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# REPORT IN RELATION

TO

# SUGAR AND HYDROMETERS.

30th Congress, 1st Session. [SENATE.] Ex. Doc., No. 50.

# REPORTS

FROM THE

## SECRETARY OF THE TREASURY,

OF

## SCIENTIFIC INVESTIGATIONS

IN RELATION TO

# SUGAR AND HYDROMETERS,

MADE, UNDER THE SUPERINTENDENCE OF

PROFESSOR A. D. BACHE,

BY

PROFESSOR R. S. McCULLOH.

Revised edition, by order of the Senate.

WASHINGTON:
WENDELL AND VAN BENTHUYSEN, PRINTERS.
1848.

Chem 7808.48

1866, Dec. 4.

# PREFACE.

The Senate having ordered a revised edition of the reports contained in this document to be printed, the labor of that revision was cheerfully undertaken without compensation; and it has been executed as faithfully and thoroughly as time and other circumstances have permitted. A careful revision, particularly of those portions which relate to the manufacture of sugar, was very necessary, for the reasons: that, in the first or preliminary report, opinions had been expressed which subsequent and more complete information modified; that the third report was originally written so rapidly, and with such little opportunity for correction, that the occurrence of errors in it could not be entirely prevented; and that inaccuracies might have misled the manufacturers. To have recast the whole series and presented the parts relating to the sugar industry in an entirely new and digested form, with such additional information as the progress of science and the arts has recently developed, would, in the opinion of the writer, have rendered it more complete and better adapted to the wants of those engaged in that industry. But to perform this, neither authority, time, nor the requisite facilities were possessed by him. To supply, though but in part and imperfectly, what such a work might have contained, as well as to avoid changing and interpolating the text of the original reports to a very considerable extent, an appendix has been added. It, however, is by no means complete, and is not designed to present all that is new and important, but only some matters which are considered worthy of attention. To others better qualified, by practical as well as theoretical knowledge, the important task of furnishing a complete treatise on the sugar industry should be left.

R. S. McCULLOH.

MINT OF THE UNITED STATES,
*December* 12, 1848.

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28th CONGRESS, 2d Session. [ SENATE. ] EXECUTIVE.

# LETTER

FROM

# THE SECRETARY OF THE TREASURY,

COMMUNICATING

*A report of chemical analyses of sugars, molasses, &c., and of researches on hydrometers, made under the superintendence of Professor A. D. Bache by Professor R. S. McCulloh.*

---

FEBRUARY 21, 1845.
Read, and ordered to be printed.

MARCH 3, 1845.
Ordered that 500 additional copies be furnished for the use of the Senate.

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TREASURY DEPARTMENT, *February* 19, 1845.

SIR: I have the honor to transmit, for the information of the Senate, a letter from Professor A. D. Bache, communicating a report of chemical analyses of sugars, molasses, &c., made under his superintendence by Professor R. S. McCulloh, in obedience to a resolution of the House of Representatives passed 21st July, 1842; and of researches on hydrometers, in compliance with a request of this department, made in consequence of representations that the present system of ascertaining the strength of distilled spirits is inaccurate, and under the authority of an act of Congress approved 12th January, 1825.

I am, very respectfully, your obedient servant,

GEORGE M. BIBB,
*Secretary of the Treasury.*

HON. WILLIE P. MANGUM,
*President of the United States Senate.*

*Letter of Professor A. D. Bache, transmitting a report of inquiries and experiments, made under his superintendence, by Professor R. S. McCulloh, on sugars, hydrometers, &c.*

OFFICE OF WEIGHTS AND MEASURES,
*February* 17, 1845.

SIR: On the 13th of March last, I was requested by the Treasury Department to undertake the experiments necessary for the comparison of hydrometers in reference to their use in the collection of the revenue. This request was stated in the letter, hereto annexed, of the Secretary of the Treasury, the Hon. J. C. Spencer, to have been made in consequence of representations to the department that Dycas's hydrometer, for testing the proofs of distilled spirits and liquors, used in the custom-houses of the United States, was not as accurate as was desirable. The department, at the same time, put at my disposal one of Dycas's instruments, together with one by Tucker & Dwelle, of Boston, and one of Sikes's hydrometers. There were others, also, at the office of weights and measures.

By an act of Congress, approved on the 12th of January, 1825, "the Secretary of the Treasury" is "authorized, under the direction of the President of the United States, to adopt and substitute such hydrometer as he may deem best calculated to promote the public interest, in lieu of that now prescribed by law, for the purpose of ascertaining the proofs of liquors;" and the subject appears to have received attention from the department at different times, without, however, definitive action in regard to it.

In accepting the duty thus assigned by the department, I reserved to myself, on a review of the ground of inquiry and a consideration of the experiments to be made, with the time within which the department required their results, to ask for an assistant, to whom the inquiries and experiments might be committed, under my direction.

In June last, I was requested further to undertake the scientific investigations required by the act of Congress of the 3d of March, 1843, in relation to sugar and sirups, and to the saccharine matters contained in them, and to connect these with researches into the saccharine and extractive matters in various kinds of liquors. It was plain that the investigations thus required, together with the former ones, relating to hydrometers, could not be accomplished in any reasonable time, without putting aside the adjustment and comparisons of the weights and measures. I therefore proposed to the department to appoint an assistant, who might, under my direction, make the investigations and researches required; and, on the request being granted, nominated Professor Richard S. McCulloh, formerly professor of mathematics, natural philosophy, and chemistry, in Jefferson College, Pennsylvania, as assistant in these inquiries. By this arrangement the department has had all the advantage of the attainments of Mr. McCulloh as a mathematician and chemist, the devotion of his time solely to these objects, by which they have been rapidly advanced, and of whatever benefit it originally proposed to itself in my direction of the work. In

justice to myself, I ought here to remark, that no compensation was asked or received by me for the superintendence in question.

After the appointment of Professor McCulloh, the general course of proceeding in the inquiries was soon marked out, and the work commenced. We have since conferred together, and corresponded frequently about the details of the inquiries and researches, but the discussion of the various questions belongs to him alone. The able report of Professor McCulloh, which I have now the honor to submit to the department, shows that I did not overrate the advantages of his services. This is, however, to be considered a report in part only, several questions being still reserved for examination, and time not having yet served for the full investigation of others.

The report consists of two parts: the first, on the analysis of sugars, sirups, and molasses; and the second on hydrometers. In the first, the different methods of ascertaining the quantity of cane sugar present in a pure solution are given, the details of the methods by evaporation, by specific gravity of the solution, by fermentation, and by the polarization of light, and the application of the two last methods to the analysis of mixtures of different kinds of sugars are discussed. A popular exposition of the method by the polarization of light is followed by a statement of the modes of research and results of Biot and Ventzke, and a description of the apparatus used by them. The methods and formulæ are then applied to examples of analysis, and the various steps in experiment and calculation are minutely given. Practical remarks follow, in regard to the different compositions of molasses; the error of estimating the value of molasses by specific gravity; the steps in the manufacture of sugar, especially in relation to those where improvements are most desirable, and the researches required for improvement; the vacuum and steam process, and the sources of its advantages; the alleged frauds upon the revenue in the importation of molasses; the necessity and value of researches on saccharine substances by the methods explained in the report.

In the second part of Professor McCulloh's report, the hydrometer is discussed. The mathematical and mechanical theory of the instrument is given and applied to its graduation, to explain the origin of the different scales in use, to the corrections required, and to the effect of injuries to metallic hydrometers by indentations. The advantages of the decimal scale for hydrometers are pointed out, and the mode of adapting the decimal scale hydrometer to use for liquids of different specific gravities is explained. The different materials of which hydrometers may be made, the methods of manufacture, and the conditions necessary to secure accuracy, are discussed. The description of the principal hydrometers, with an examination of their advantages and defects, and of their theory, follows, and includes the principal hydrometers of France, England, Germany, Holland, Switzerland, and the United States. The decimal scale hydrometer is compared with others, and its advantages in point of simplicity are insisted upon. The remarks in regard to the graduation of hydrometers lead naturally to a discussion of the temperature of the maximum density of water, in reference to

which a very full examination of the experiments of Despretz is given, and the method of least squares is applied to calculate the most probable value of the temperature in question from his researches. The results of experiments on the dilatation of mixtures of water and alcohol are collected and represented graphically, the subject of the proof of liquors is discussed, and the report closes with a comparison of different hydrometers.

From the data thus brought together, aided by the results of the experiments which they suggest, it will be easy to meet the practical questions in hydrometry, and to furnish to the government the means of securing uniformity in the collection of the revenue, and to practical men generally accurate instruments, adapted to the wants of their different arts. I have not thought it necessary, or even desirable to delay the presentation of this report for the sake of rendering it more complete, as the supplementary matter may be appropriately given in a further report.

Very respectfully, yours,

ALEXANDER D. BACHE.

Hon. George M. Bibb,
*Secretary of the Treasury of the United States.*

---

*Letter from the Hon. John C. Spencer, Secretary of the Treasury, to Professor A. D. Bache, in relation to experiments upon hydrometers.*

Treasury Department, *March* 13, 1844.

Sir: It is represented to the department that Dycas's hydrometer for testing the proof of distilled spirits and liquors, directed to be used for this purpose by an act of Congress passed as early as the year 1790, and still continued in use at the respective custom-houses in the United States, does not probably exhibit as much accuracy in this respect as some more modern instruments used for the purpose mentioned. It is therefore deemed important to the interests of the revenue that a careful and thorough investigation of the subject should be had; and I wish you to undertake the matter, and to institute suitable experiments with different hydrometers, and furnish me with the results. The department has in its possession one of Dycas's instruments, together with one invented by Tucker & Dwelle, of Boston, and also Sikes's hydrometer, said to be used at the custom-houses in England, all of which will be furnished you. It is believed that there are some instruments of the kind in the weights and measures or coast survey office, procured for public purposes by the late Mr. Hassler.

To place you in possession of all the information on the subject in the possession of the department, I would add, that, by the act of Congress of the 12th of January, 1825, the Secretary of the Treasury, under the direction of the President is authorized "to adopt and institute such hydrometer as he may deem best calculated to promote the public interest, in lieu of that now prescribed by law

for ascertaining the proofs of liquors, &c." It appears, that shortly after the passage of this law various tests and examinations were made, with the different instruments then in use, both at Washington, by the late Doctor Staughton, and at the United States mint in Philadelphia, by Doctor Patterson, father of the present director of the mint. The examination at this place was made with Dycas's hydrometer, Gay Lussac's alcoholometer, and an instrument invented by Tucker & Dwelle, of Boston. Mr. Secretary Rush, in giving the result of this examination, states that the "two former were found to give the same result, or with scarcely a perceptible difference; and each indicated a higher degree of strength in the liquor than the latter." The report of director Patterson's observations was lost by the conflagration of the treasury building, in the year 1833; but, as no other instrument was substituted in the place of Dycas's at that time, it is probable no change was deemed expedient.

As some of these instruments are stated to be too delicate for ordinary use, it is proper that regard should be paid to that fact in the case of any hydrometer you may recommend, and due allowance made for their falling into unskilful hands, which is likely to be the case at the custom-houses.

I am, very respectfully, your obedient servant,

J. C. SPENCER,
*Secretary of the Treasury.*

Professor A. D. BACHE,
*Superintendent of Weights and Measures, Washington.*

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# REPORT

TO

*Prof. A. D. Bache, of researches made under his superintendence, by Prof. R. S. McCulloh, in relation to sugars, hydrometers, etc.*

WASHINGTON, *February* 18, 1845.

DEAR SIR: I have the honor to submit the following report of the progress I have made in the researches confided to me. You will, I trust, find that I have followed your instructions and advice; and the details herein set forth will be sufficient, together with such oral and informal written communications as I have from time to time made, to enable you to judge of the manner in which I have performed my task.

As the following report is intended for yourself as well as for general information, I have felt at liberty to go more into detail and to render it more scientific than I should otherwise have done. Since, however, the purely scientific parts will be of little interest to many, I have designated by a star, in the table of contents, such articles as would possibly be found most interesting to those who desire rather to know simply the results obtained.

Considerable time of necessity, elapsed before I could procure the requisite apparatus: this enabled me more thoroughly to discuss the various memoirs contained in scientific journals and transactions; and you will, I hope, find that the time thus employed was not unprofitably spent.

I cannot refrain from expressing to you my grateful sense of the facilities I derived from my friend Professor Robert M. Patterson, director of the United States mint, through whose kindness I obtained books from the library of the American Philosophical Society, and from whom I also received not only valuable information, but many suggestions which I found of service to me. I would also acknowledge the important services of Messrs. Booth and Boyé, in whose well furnished laboratory I performed my chemical investigations, who frequently repeated my observations, and who furnished me much useful information and imported the valuable apparatus I employed. I am indebted to them for a full report of the labors of Ventzke, in Berlin, and of their own analyses of molasses, made in July, 1843. The relationship which subsists between us should not, I think, prevent my mentioning the valuable services of my younger brother, William J. McCulloh, who kindly undertook the laborious task of performing independently most of the calculations contained in this report, and discharged it faithfully; thus checking my work. Lastly, I would express my thanks

to those gentlemen of the Treasury Department who have facilitated my labors, and particularly to Mr. Crabb, of the Comptroller's office.

I frequently use the terms *cane or crystallizable sugar*, *uncrystallizable sugar*, *left and right polarizing sugar*, *grape sugar*, *fruit sugar*, *starch sugar*, *liquid sugar*, *etc.*; and it is therefore fit that I should define the precise meaning of such terms, which I employ *technically*, especially as, in ordinary language, sugar is erroneously regarded as one substance, varying only in purity, color, and consistence.

A sweet taste and salt-like structure were sufficient in the days when accurate science had not cast its light upon the nature and properties of saccharine substances, to obtain for a body the name of sugar; and thus acetate of lead, composed of vinegar and the protoxide of lead, acquired the name of *saccharum saturni* or *sugar of lead*. Such loose employment of language is inadmissible in exact knowledge, and hence chemists have found it necessary to confine the application of the term *sugar* to such organic substances as have, superadded to a sweet taste, the property of being susceptible of alcoholic fermentation; there are a number of different substances which are therefore *sugars*, while some of organic origin, and of very sweet taste, are excluded from the class because they do not undergo vinous fermentation. Such, for instance, as *mannite*, the principal ingredient of manna.

By *cane or crystallizable sugar*, chemists and refiners mean not only the extract of the juice of the sugar cane, but the same substance, however produced. The beet, the maple, the melon, the carrot, the turnip, and the green Indian corn plant, all yield *cane or crystallizable sugar*, in greater or less proportion. Hence, *cane sugar* means that sweet substance which is susceptible indirectly of vinous fermentation; which, when pure, is perfectly white, crystallizes in prisms, and is of the specific gravity 1.6065; of which the chemical composition is carbon, hydrogen, and oxygen, the two last in proportions to form water; which, in solution, possesses the property of circular polarization of light, and the distinguishing feature, with relation to all other known sugars, of being invertible by acids without the aid of heat; and which behaves with chemical tests, and particularly the copper test of Trommer, in the manner described in the subsequent part of this report.

By *uncrystallizable sugar* is designated in contradistinction *any other* sugar than cane sugar. The distinction of *left and right polarizing sugar* will have no obscurity to any one who may read the succeeding chapter.

Besides cane sugar, and *lactine*, (milk sugar,) chemists agree in admitting the existence of another variety, to which M. Dumas has applied the generic name of *glucose*, but which Liebig and others have usually called *grape sugar*. Liebig includes under this head not merely the sugar of grapes and acid fruits, but also sugar of starch, diabetic sugar, and all that class of sugars which are produced by the action of acids on vegetable fibre, such as paper and linen rags, or on cane sugar, sugar of milk, starch, &c. And it is

in this extended though vague sense that I have frequently employed the term *grape sugar*, which in strict propriety should be confined to that sugar alone which is obtained from grapes. Yet Liebig remarks, that "although the identity of different kinds of sugar classed under the name of *grape* sugar or *glucose* be generally admitted, it is important to know that there are certain facts apparently irreconcilable with this notion." Also, M. Dumas says :* "I believe that glucose will be found identical, whatever be its origin; whether from honey and fruits, or from diabetic urine, or produced by chemical action upon starch and ligneous fibre. But this opinion, in which chemists do not generally concur, can only be established (*entièrement justifiée*) by subjecting all these varieties to multiplied and very refined comparative tests." And, further, "*glucose*, properly so called, comprises, besides sugar of starch, that of diabetes, and perhaps agglomerated (*mamelonné*) grape sugar. It is necessary to observe, however, that glucose obtained from starch, whether by great pressure, and a small quantity of oxalic acid, or by the long continued action of acids, differs in rotary power from ordinary glucose."

Biot has shown† that both Liebig and Dumas have erred in giving to *glucose or grape sugar* too wide an interpretation, and that other chemists have gone further than M. Dumas anticipated, and applied his term *glucose* even to the saccharine product of cane juice under the influence of spontaneous fermentation, or of acids after saturation; to which product M. Bouchardat has given the name of *saccharo glucose*. Biot shows that Liebig, in his Treatise on Organic Chemistry, by comprising under *glucose* diabetic, grape, starch, and fruit sugars, confounds liquid sugar of honey and liquid grape sugar with solid sugar of grapes, and the latter with sugar of starch; that, of all the distinct kinds of starch sugar which MM. Biot and Persoz found to exist, Liebig mentions but one; and that saccharo-glucose is by him confused with the sugar of grapes and sugar of starch; in short, that while the distinguished chemist of Giessen hesitated to pronounce all kinds of glucose identical, by reason of differences in points of fusion, he was "entirely without the thread of the labyrinth which optical properties only could have furnished him," and that of these he speaks loosely and inaccurately.

Glucose, or grape sugar, as it is more commonly called, of whatever origin, does not crystalize like cane sugar, in large regular crystals, but in minute fibrous crystals, the shape of which is not distinct, but which form tubercular masses. On this account, it is very frequently called by French writers *sucre mamelonné*. Its taste is at first farinaceous, then feebly sweet, and mucilaginous when it begins to dissolve in the saliva. Its sweetening power is only two-fifths of that of cane sugar; hence, in mixture with cane sugar, it greatly impairs the quality of the article for all domestic purposes. It is also much less soluble in water than cane sugar, and dissolves with difficulty even with protracted stirring; according to M. Bau-

* See Traité de Chim. appliq. aux Arts, t. 6, p. 274; Paris, 1843.
† See Comptes Rend. des Séances de l'Acad., t. XV, p. 636.

drimont, water at 73° Fahrenheit is saturated by 0.635 of its own weight of grape sugar.

There is still a third class of sugars, which seem to exist only in the liquid state, and to pass into glucose when evaporated to dryness. Of these less is accurately known than of either of the preceding classes. These sugars have borne among chemists the name of fruit or liquid sugar; M. Soubeiran has proposed the term *chylariose* for them. M. Biot found that the sugar contained in fresh grapes differs from glucose in rotating the plane of polarization in the opposite direction. Cane sugar also, in solution, is converted by fermentation and acids into a peculiar sugar which polarizes to the left; and this sugar exists in large quantity in molasses which has been long made. Both of these liquid sugars are by evaporation converted into right-polarizing glucose, and cannot afterwards be made to polarize as at first to the left. M. Dumas remarks :* "Cane sugar forms a species perfectly distinct. We do not know in what consists the modification which renders it uncrystallizable in molasses, but it is beyond doubt that there exists a species of cane sugar which has been rendered uncrystallizable. Starch is converted by acids into a distinct sugar, which I call *glucose;* this may also become incapable of assuming the solid state; there is therefore an uncrystallizable glucose."

All these sugars are composed chemically, as are also gum, vegetable fibre, starch, &c., of carbon, hydrogen, and oxygen, the two last in proportions in which they form water; hence chemical actions which deprive them of water, or impart it to them, convert often one into another. Sugar may be considered also as composed of carbonic acid, and alcohol, and very slight disturbances of the forces of attraction between their atoms will bring to pass this change of arrangement of their elements; such is the explanation of the phenomenon of *vinous fermentation.* Alcohol, by combining with the oxygen of the atmosphere, is converted readily into vinegar; hence the reason of the modern German process of allowing spirits to trickle through a pile of shavings, or of hay, thus exposing a large surface to the air, and quickly converting it into vinegar.

I have been thus minute in these preliminary remarks, that the difficulties of answering the question in the resolution of the House of Representatives, "what quantity of sugar is contained in different saccharine substances?" may be understood and appreciated by those who proposed that question; and that the propriety of the course pursued in these investigations, to attend chiefly to matters upon which the experience of the government shows knowledge to be most requisite, may fully appear. Before the above-mentioned question can be directly answered, it should be stated, *what kind* of sugar is meant. In molasses, for instance, there are *at least two* kinds of sugar, 50 per cent. of good crystallizable cane sugar, and a large proportion of liquid sugar, mixed probably with grape

* See Traité de Chim., app. aux Arts, t. 6, p. 270.

sugar, (saccharo-glucose.) In raw or brown sugar there are contained, besides impurities, both cane sugar and grape sugar. So also much of the so called refined sugar contains a large quantity of grape sugar, which constitutes a great impurity; for its sweetening power is two and a half times less than that of pure crystallized cane sugar. And such is the practical effect of this impurity, that, as I had recently occasion to learn, three pounds of pure sugar go as far in preserving fruits and other domestic uses as four pounds of the common or imperfectly refined loaf sugar of our markets; a fact which is important to be known in domestic economy, for the house wife's rule of "pound to pound" should be changed to three-quarters of a pound to every pound.

The necessity of investigating the distinctive properties of different sugars, before chemistry will have attained accuracy in this important branch of that science, will appear from the confusion which the preceding remarks show to exist. It is no reproach to chemistry, however, that such investigations have yet to be made, for as an exact science it is but half a century in age, while organic analysis is in its infancy, and most of those to whom we owe the first accurate analyses of organic substances, as well as the methods employed, are still in the prime of life and usefulness. The quantitative and beautiful method by the circular polarization of light is scarcely known generally to chemists; and it is perhaps the dawn of a new branch of science, to which M. Biot has already given the name "optical chemistry." To the young analytical chemist it opens a wide and rich field of research, and to the arts it has already yielded abundant fruit, while it bids fair to illumine many of the dark recesses of medical science.

# SECTION I.

***On the quantitative and qualitative analysis of sugars, sirups, and molasses, and particularly those derived from the cane.***

1. Cane sugar is one of the numerous class of organic substances whose elements seem to be held together by chemical forces of very feeble intensity, so that very slight causes are sufficient to alter its nature and change it into entirely different bodies. By fermentation it is converted into mucilage, lactic acid, or alcohol and carbonic acid. The influences exerted upon it by heat, atmospheric air, and nitrogenous substances, are very powerful and important, constituting as they do obstacles to the planter and refiner, which they have earnestly but in vain endeavored to overcome. Science has been called to their aid with but little effect; and though of late years important improvements have been made, especially in refining, the principal difficulties in the manufacture of sugar are still unremoved. It will not, therefore, appear strange that the chemist has found his trouble, also, in the investigation of this substance; the agents which he usually employs in analysis, without so destroying the substance experimented upon that it may not be separated again unchanged, sever the elements of cane sugar so completely from their mutual combination, that it seems impracticable to reunite them; and, indeed, the present state of chemical science upon this subject goes far to show that it is scarcely more possible to reconstruct the atom of sugar, when once so destroyed, than it would be to restore the crushed plant from the mill to the condition in which it stood in the field. High rewards have been offered by governments, and by the Academy of Sciences of Paris, for an exact chemical method of separating and analyzing the different varieties of sugar in mixture with each other or foreign substances. Such a method is yet undiscovered. Although that almost mathematical accuracy which the modern chemist is required to attain in his investigations, and which will not admit of errors in his weighings of even the hundredth part of a grain, has not been reached in the analysis of sugars, we possess methods which, for all practical purposes, are sufficiently precise, and which give earnest that exact chemical science will not long allow even this unstable substance to elude its skill. These methods will now be described.

2. If it be required to ascertain the quantity of sugar contained in a solution composed only of pure water and cane sugar, this may be done by four different methods, two of which are applicable to such solutions only, while the remaining two may likewise be employed when the solution contains other substances besides cane sugar. These four methods are: by evaporation, by specific gravity, by fermentation, and by the circular polarization of light.

3. *By evaporation.*—This is best performed under the receiver of an air pump, as heat, if protracted, will convert cane sugar into sugar not unlike grape sugar, or that obtained from starch by the action of acids, diastase, &c.; but for practical purposes, evaporation of small quantities in a porcelain capsule, by a water bath, so that the heat may not exceed 212° Fahrenheit, will give results of sufficient accuracy. The open flame of a lamp would be apt to burn or caramelize a portion of the sugar. When an air pump is employed, a vessel containing concentrated sulphuric acid should be used to remove vapor from the exhausted receiver.

In nice scientific investigations, it becomes important to fix the standard which shall be regarded as dry, solid cane sugar. Brown sugars usually contain a large quantity of molasses and hygrometric moisture. And even pure white crystallized sugar exists in several states of aggregation, which vary in this respect; rock candy and loaf sugar, fine and coarse grained, more or less spongy in its texture, differ from each other, slightly it is true, yet sufficiently to exert an appreciable influence in very exact researches. Large crystals are apt to enclose portions of the mother liquor between their laminæ; for this reason, rock candy, when perfectly white and transparent, is not a proper standard, unless it first be powdered finely and dried. Porous loaf sugar would also be an improper standard, on account of hygrometric moisture held between its crystals by capillary attraction. M. Biot, who had occasion to make a series of very nice researches upon this subject, takes as a standard finely powdered rock candy, perfectly white and pure, and dried by exposure for a long time to the ordinary atmospheric temperature in a dry room. If stove dried, or by means of an air pump, the hygrometic state would not be that under which sugar usually exists in commerce; and this, its mean or normal condition, is certainly that which should usually be understood as designated, when not otherwise expressly stated. In my own researches I have employed, as a standard, powdered loaf sugar, which had remained in a dry room for eighteen months, refined by J. S. Lovering & Co., of Philadelphia, by the vacuum process, and without the use of blood, eggs, or any other objectionable substance; the purity of which I ascertained by the most delicate tests; and I could not detect in it the slightest trace of foreign matter. The beauty of the sugar refined by this house exceeds that of any foreign sugar I have seen; and having been permitted to inspect their establishment, and carefully examine the process of refining there employed, through all its different stages, I feel assured that the sugar I adopted as a standard had been subjected to no action which could impair its perfect purity.

4. *By specific gravity.*—When sugar is dissolved in water, the solution becomes heavier, or possesses greater density; by mixing, therefore, accurately determined weights of water and sugar, in various proportions, and ascertaining experimentally the weight of a constant volume of each, tables may be formed which will tell by inspection the quantity of sugar contained in a solution whose

density is either given or ascertained by means of an ordinary balance, according to the well known methods, or with a hydrometer graduated to read specific gravites. Table I of the appendix constructed by Niemann,* and pronounced by Ventzke to be accurate, is intended for this purpose. It is adapted to the temperature of 63½° Fahrenheit, (17½° centigrade,) but may be used for temperatures near to that; for a slight difference of temperature would only affect the fourth decimal place. As hydrometers graduated to read specific gravities are rare, costly, and of difficult construction, I give also table II, constructed by M. Payen, which shows the quantity of sugar for each degree of Beaumé (*pèse sirop*,) the hydrometer usually employed by refiners and planters. As the instrument of Beaumé often varies, however, even by whole degrees, according to the skill and standard of the maker, it should always be verified by comparing it with the indications of solutions of sugar mixed for the purpose in the proportions of the table. A hydrometer might readily be constructed, the divisions of which should express the per centage of sugar in a solution; and such an instrument would be found simpler, and preferable to any other.

The use of hydrometers, though very convenient for pure solutions of crystallizable cane sugar, becomes inadmissible when grape sugar, molasses sugar, or other substances, are combined with it; for each substance dissolved affects the density, and it is impossible to distinguish the relative portion of the combined effect which is to be ascribed to the agency of each different ingredient. For this reason hydrometers will not determine the quantity of cane sugar in molasses.

5. Before stating the details of the methods by fermentation and polarization, as these methods are applicable to solutions containing other substances besides cane sugar, I shall give the tests to be employed in the qualitative analysis of sugars; the most delicate and important of which is the copper test of Trommer, as communicated by Mitscherlich to the Berlin Academy of Science.† The solution is treated with aqua potassæ, and then a dilute solution of sulphate of copper is added. Cane sugar becomes of an intense blue color; it may even be boiled with an excess of potash without separation of protoxide of copper, which occurs only after protracted boiling. When the experiment is performed without heat, the solution remains unchanged for several days, and protoxide of copper separates only after long boiling. A slight separation of protoxide of copper occurs, if it be allowed to stand a long while; but, even after several weeks, the reduction of the oxide of copper does not perfectly take place. If a solution of grape sugar and potash be treated with a solution of sulphate of copper, until the hydrated oxide of copper, which separates, is redissolved, after a short time, and at the ordinary temperature, protoxide of copper separates; if we warm the solution, *immediately* the protoxide se-

* See Annalen der Pharmacie, ii, p. 340.
† See Annalen der Pharmacie. Leibeg and Wöhler, vol. 39, p. 360.

parates, and the solution becomes colorless, even if a small quantity of sulphate of copper has been added. A solution which contains a hundred thousandth part of grape sugar gives, when boiled, a visible precipitate; and when it contains a millionth, by transmitted light the solution has a reddish color. We may by this test show that cane sugar, before it enters into fermentation, is first converted into a sugar resembling grape or fruit sugar. Milk sugar behaves with the copper test like grape sugar, but causes the reduction of oxide of copper to protoxide still more rapidly. The peculiar action of this copper test is due to the extreme facility with which all sugars, *except cane*, reduce salts of copper in their alkaline solutions, when raised for an instant to boiling. Owing to the fact that boiling converts cane into uncrystallizable sugar, which might be supposed to pre-exist, this test requires to be used with care; but its delicacy is indeed astonishing.

With the copper test, a solution of gum gives a blue precipitate, insoluble in alkaline water, but soluble in pure water, which, when boiled, does not become black—a proof that the precipitate is not hydrated oxide of copper, which parts with its water and becomes black at 212° Fahrenheit; but that it is a combination of gum with oxide of copper. So likewise behave starch and gum tragacanth.

A solution of dextrine gives, without a trace of a precipitate, a deep-blue liquid, which, when allowed to stand a long time, does not change, but from which, if heated to 185° Fahrenheit, a red crystalline precipitate of protoxide of copper soon separates.

If to a solution of gum we add dextrine, we always obtain, besides a precipitate, a blue-colored liquid. Dextrine is, therefore, a distinct substance from gum. From this reaction we may readily be convinced that gum contains no dextrine. And when starch is converted, by nitric or hydrochloric acid, into dextrine; or by sulphuric acid, diastase, or animal membrane, first into dextrine, and then into grape sugar, the copper test shows that no gum is formed as an intermediate product. If a precipitate be obtained, it is still undecomposed starch, which is readily shown by a solution of iodine.

Cane sugar is readily distinguished from other sugars by the optical test of polarized light; for acids convert it, without heat, into a peculiar sugar, which polarizes from right to left, instead of from left to right, as for cane sugar, grape sugar, starch sugar, &c. And this property of being invertible by acids seems to belong to no other kind of sugar. Lime and alkalies, which do not alter the color of cane sugar, with the aid of heat, render grape sugar dark colored. Cane sugar yields no precipitate either with the acetate or subacetate of lead—a property which enables us to separate many substances from its impure solutions. Absolute alcohol does not dissolve it to any extent, while it readily unites with liquid or uncrystallizable molasses sugar.

6. Upon these two last-mentioned properties depends the method followed by my friends Messrs. Booth and Boyé, for the analysis of molasses, and which I give as communicated by them to me.

The results they thus obtained were embodied in a report made August 1, 1843, to Calvin Blythe, esq., collector of the port of Philadelphia, and now on file in the Treasury Department, a copy of which (marked A) is also annexed.

In a bottle, carefully weighed, put about 150 grains of molasses and an equal weight of clean white sand, to render solution more easy by separating the viscid mass; then add the strongest alcohol of the shops, and digest the whole in a water bath for nearly an hour, repeatedly shaking the bottle, to dissolve the molasses sugar. The bottle is allowed to stand undisturbed for several hours, that the solution may become perfectly clear; and it is then decanted. After this operation of washing has been repeated twice or three times, the bottle and its contents are carefully dried by means of a water bath, and weighed. The loss in weight is the amount of uncrystallizable molasses sugar dissolved. The alcoholic solution may be evaporated and examined, to ascertain that it contains no considerable quantity of any other substance.

The residue in the bottle is dissolved in water, and filtered, to separate the sand. The extractive matter is then separated from the filtered solution by precipitation with subacetate of lead, carefully added, so that perfect neutrality may be obtained. The precipitate is collected upon a counterpoised filter, dried in a water bath, and weighed. The oxide of lead, separated from it by sulphuric acid, gives, by subtraction, the quantity of organic matter in its composition.

From the remaining solution, which contains cane sugar, we may obtain the quantity by fermentation, evaporation, or polarization.

This method, just described, I followed only in one instance, finding it more convenient to employ optical than chemical processes.

7. *By fermentation.*—If we mix yeast with a dilute solution of sugar, and allow the mixture to remain at a temperature of 80° to 90° Fahrenheit, after a short time fermentation will ensue, carbonic acid is disengaged, and alcohol formed. Thénard states that one part of yeast is sufficient for five of sugar; and the proportions of water and sugar which are best adapted to the transformation are, according to M. Colin, one of sugar and three or four of water. When there is but one of sugar to eight of water, the action is said to be too slow. In my own experiments I have employed solutions still more dilute without inconvenience.

Now, as the composition of cane sugar is very accurately determined, if it were converted entirely into carbonic acid and alcohol, we might ascertain the amount of either, and calculate the exact quantity of sugar from which it was formed. A small quantity of lactic acid is, however, produced at the expense of the sugar, which combines with ammonia from the decomposing ferment; yet the quantity of lactic acid is very small, if the fermentation be properly conducted; and as it is proportional to the nitrogen of the yeast employed, we might obtain a formula for calculating the sugar transformed into lactic acid from the weight of the yeast. Sugar, under peculiar circumstances, undergoes a particular trans-

formation, known as the *viscous* fermentation; but this never occurs when the process is conducted properly.

From the preceding it will appear that analyses of sugar, by fermentation, though not rigorous, are yet sufficiently accurate for practical purposes. Pelouze, in his investigations of the juice of the sugar beet, determined the quantity of sugar contained by the alcohol yielded in fermentation. But it is easier to ascertain it from the carbonic acid, the quantity of which may be measured over mercury or obtained by loss of weight; the latter is preferable. For this purpose, the usual apparatus, consisting of a flask or bottle, fitted with a chloride of calcium tube, is employed. The sugar or saccharine substance is first accurately weighed, then introduced into the flask, and dissolved in a considerable quantity of water; a small portion of yeast being added, the whole is weighed. The moisture which accompanies the carbonic acid is absorbed and retained by the chloride of calcium. After the fermentation has ceased, the carbonic acid remaining in the bottle must be expelled, by sucking atmospheric air into it with a tube; and then the apparatus should be again weighed; the loss of weight is the quantity of carbonic acid which escaped. Now, every 100 parts, by weight, of carbonic acid, correspond to 195, nearly, of cane sugar; we therefore determine the latter when we ascertain the weight of the former. During the fermentation, the mixture is apt to froth and swell up, so as even to find its way through the chloride of calcium tube, and thus cause a failure of the operation. I have found a small quantity of olive oil floating on its surface, which I tried at the suggestion of my friend M. H. Boyé, an effectual preventive of this accident. For the qualitative analysis of sugar, M. Quevenne has shown that fermentation is a very delicate test; yet it is inferior to the copper test.*

8. *By circular polarization.*—To a remarkable optical phenomenon, discovered by Arago in crystallized quartz cut perpendicularly to its axis, and also by Biot in liquids of vegetable or animal origin, Fresnel has given the name of *circular polarization*. Biot has investigated the subject with remarkable skill and success, and furnished to the chemist a means by which he may impress light, that most subtle and intangible of the agents of nature, into his service, and substitute it for the balance in determining weights of organic matter with all requisite accuracy—a discovery as singular as it is beautiful.

When a ray of ordinary light is transmitted through a rhomboid of Iceland spar, or any crystal which does not belong to the regular system with three equal rectangular axes of symmetry, it will, in almost every direction, be divided into two rays of equal intensity, refracted at different angles, one in the plane of incidence, the *ordinary ray*; the other in a different plane, the *extraordinary ray*. If it comes from a luminous body, as for instance a candle, then an eye looking through the crystal will behold two images of

* See Journal de Pharmacie, t. xxvii, p. 589.

equal brilliancy. This is the property usually spoken of as that of *double refraction*. If the crystal be revolved in a plane at right angles to the ray as an axis of rotation, then will the images appear to revolve round each other, but their intensity will not vary.

If, however, the ray be one which has already passed through a doubly refracting crystal; or which has suffered reflection from a polished surface of glass at an angle of 35° 22′, then will it possess peculiar properties, to which Malus, their discoverer, has given the name of *polarization*. If a ray of polarized light be transmitted through a doubly refracting crystal, it is divided into two rays of *unequal* intensity, or an eye would behold two images of *unequal* brightness. Let $i$ be the incident ray, $x$ the angle formed by the principal section of the second crystal with that of the first, or with the plane of reflection, $o$ the ordinary ray, and $e$ the extraordinary; then will

$$o = i \cos.^2 x, \qquad e = i \sin.^2 x,$$

the sum of which is always equal to $i$, the incident ray. When $x = 0$, or $x = 180°$, then $o = i$ and $e = 0$. And when $x = 90°$, or $x = 270°$, we have $e = i$, and $o = 0$. Hence, at each quadrant, the ordinary, and extraordinary ray alternately disappear, and these two rays are always complementary to each other.

Of doubly refracting crystals, some are symmetrical about one particular line of figure, others unsymmetrical; they thus constitute two distinct classes. If a face be cut any where upon these crystals, a ray of light falling perpendicularly upon it will generally suffer double refraction. But for crystals of the first class, there is one position of the plane or face, for which the normal ray is transmitted without division; while for crystals of the second class, there are two or more such positions. The normal ray for such planes is called an *optical axis*, and crystals are consequently distinguished *as crystals of one axis* and *crystals of two or more axes*.

When a normal ray of homogeneous polarized light falls upon a plate of a doubly refracting crystal of one axis, cut perpendicularly to that axis, it is transmitted unchanged. To this law quartz presents the only exception among crystallized bodies; and it is to the peculiar phenomena presented alike by this substance and certain organic liquids, under such circumstances, that the term of *circular polarization*, or *rotation*, is applied. The ray which has passed through them remains polarized, but its plane of polarization has revolved about the axis; plates cut from some specimens of quartz cause it to revolve *to the right*, from others *to the left*. In that variety of quartz which Haüy called *plagiedral*, the inclination of the plagiedral faces has been discovered, by Sir John Herschel, to determine and be intimately connected with the direction of the rotation. So likewise liquids cause rotation, some to the right, others to the left. The more refrangible rays of the spectrum have their planes of polarization displaced the most;

thus the plane of the red ray, when that ray is transmitted through a plate of quartz one millimetre in thickness, will deviate, according to Biot, by an angle of 17° 29′ 47″; while the plane of the more refrangible violet ray will rotate through 44° 4′ 58″. Hence, a ray of white polarized light will be decomposed into rays of every color polarized in different planes. Biot has shown that the angle of deviation for each homogeneous ray will vary proportionally to the thickness of the stratum of liquid through which it passes; and that the angles of deviation for the different colors will, for each respective thickness, be to each other in constant ratios; which ratios Biot finds also to be the same for every active substance, except tartaric acid and its combinations.* The foregoing facts will render the terms employed of distinct signification, and at the same time serve to explain more fully the phenomena upon which the method of chemical analysis by circular polarization depends.

In the year 1815, M. Biot communicated to the Academy of Sciences the discovery that certain liquids, such as essence of turpentine, oil of citron, spirits of camphor, &c., possess the property of circular polarization. And the previous investigation which he had made of the laws of that phenomenon, as presented in quartz, prepared him to seize upon its more hidden and feeble indications in liquids.

Yet it was not before 1832 that he had brought his apparatus and methods to the degree of perfection requisite for organic chemical analysis. By a series of researches, made with the greatest care, M. Biot arrived at the following laws.† *The angle of deviation for each ray of homogeneous light is proportional to the length of the tube or stratum of liquid it contains, the density remaining constant. It is proportional likewise to the number of active particles in the liquid.*

A pure solution of cane sugar, containing ten per cent. of sugar, will rotate the plane of polarization through twice the angle produced by one of five, the length of the tube being the same, nor will this angle vary if the solution be diluted with water, or any other inactive substance, such as alcohol, sulphuric ether, &c., if we increase the length of the tube in the same ratio. Biot found that spirits of turpentine reduced to the state of vapor at rest or in motion, or liquid and violently agitated by a mechanical contrivance moved by clock work, still retained its polarizing power unaltered. And if liquids polarizing in opposite directions be mixed, in quantities inversely proportional to their rotary powers, then will their effects be mutually destroyed, and the plane of polarization remain undisturbed. Hence it follows, that circular polarization does not depend upon the relations of symmetry or position of masses; that it depends upon the nature of the molecules themselves, and therefore is one of the characteristic properties of the substances which possess it; and that the total or integral an-

* Memoires de l'Académie, t. xv, p. 95. Ibid, ii, p. 58.
† Memoires de l'Académie, t. xiii, p. 116; t. xv, p. 100; t. xvi, p. 241.

gle of deviation of the plane of polarization for any given ray is the sum of all the infinitely small deviations produced by the molecules.

The *molecular rotary power* of a substance is therefore one of the constants of its nature. For different substances, this constant is either positive, *to the right*; or zero, *molecularly inactive*; or negative, *to the left*. Let $(\alpha)$ represent the molecular rotary power of an active substance; for instance, of crystallizable cane sugar. Then it is evident, from the preceding that

$$(\alpha) = \frac{a}{l\,\varepsilon\,\delta} = \frac{a'}{l'\,\varepsilon'\,\delta'} \quad - - - - - - - - \quad (1);$$

In which $a$, $a'$ are angles of deviation for a particular ray, e. g. the violet blue, as observed through tubes of the respective lengths $l$ $l'$; and for solutions of the densities $\delta$ and $\delta'$ containing the proportions $\varepsilon$ and $\varepsilon'$ of active matter. This is Biot's formula for the rotary power of solutions containing only one kind of active matter, and it is evidently adapted to logarithmic computation.

To render this formula more general and convenient in chemical operations, suppose the solution to be somewhat colored, sufficiently so to render it impossible for the naked eye to decide the tone of color produced by circular polarization. Then, by means of colored glasses, red, green, or yellow, we may still obtain the deviations of their respective planes, which it may be required to reduce to the corresponding deviations of the violet-blue ray, as they would have been observed by the naked eye if the solutions were perfectly colorless. Now, as stated above, the deviations of different colored rays are to each other in constant ratios, except for tartaric acid; hence, let $m$ be the coefficient by which we must multiply the observed angles of deviation to reduce them to the angles which would have been observed for the red ray, or through a glass transmitting only homogeneous red light, which glasses colored with protoxide of copper are found to do. Then

$$(\alpha') = \frac{m\,a}{l\,\varepsilon\,\delta}$$

is the general formula for deviations of the red ray, taken as a standard of comparison;* in which $(\alpha') = m\,(\alpha)$ is the rotary power for the unit of substance, and for the red ray.

The analytical chemist often finds, in his investigations of organic bodies, that substances exist in solution which cannot be separated without destroying them, or without admixture or combination with other ingredients. It is in such instances especially that the method of analysis by circular polarization has its greatest advantages. For, then, if the substance he would isolate possesses rotary power, and is the only active matter in solution, he may entirely disregard the substances with which it is mixed. On this account, distilled

* See Comptes Rendus des Séances de l'Académie, t. xv, p. 619.

or pure water is not required, and even water highly impregnated with mineral substances may be used, provided it possesses no chemical power to change the nature of the substance to be dissolved in it.

Biot has found that solutions of cane sugar, and of sugars generally, whether mixed or separate, may, as far as their optical properties are concerned, be regarded as simple mechanical mixtures. To ascertain this, they were dissolved in very different and numerous proportions, and the angles of deviation observed were found to be exactly proportional to the quantities of active matter in solution. So that determinations by this method possess all the accuracy attainable for other substances by means of a delicate balance.

As $(\alpha)$ and $(\alpha') = m\,(\alpha)$ are constants, for each chemical substance, too much care and nicety cannot be spent upon their exact determination; and this once done with the required accuracy, need not be afterwards repeated. If by rigid observations we have obtained $(\alpha)$ for the violet-blue ray, and $(\alpha')$ or the coefficient $m$ for the red ray of the protoxide of copper glass, we have by equation (1)

$$s\,\delta = \frac{a}{l\,(\alpha)} = \frac{m\,a}{l\,(\alpha')} \quad - - - - - - - (2).$$

The density $\delta$ is observed by the well-known methods for taking specific gravities, and $l$ is measured. Hence $s$ is the only unknown quantity in equation (2), and is determined by it. To explain the precise meaning of the first member of this equation—the value of which is given by the second, which contains only known quantities—if the half pint measure be defined as that which contains, at 56½° Fahr., the one-hundredth part of a cubic foot of water, and weighs ten ounces troy; and if the densities be either taken at, or reduced by calculations to, this temperature, for which that of distilled water is assumed to be unity; then as $s$ is the unknown per cent. of active matter, in each unit by weight of the solution, and $\delta$ represents the weight in ounces of a half pint of the solution, $s\,\delta$ will represent the quantity in ounces of the active substance contained in a half pint of the solution; and if we multiply by 480, we shall reduce this to grains. It is evident that $\delta$ need not be known except to obtain $s$, the per centage; and that $s\,\delta$ will, for practical purposes, often be sufficient.

If we make $c = \frac{1}{(\alpha)}$, and $c' = \frac{1}{(\alpha')}$, then equation (2) gives

$$s\,\delta = c\,\frac{a}{l}, = c'\,\frac{a'}{l};$$

where $a'$, the angle observed directly with the red oxide of copper glass, is equal to $a$, the angle of deviation of the violet blue ray, multiplied by $m$, the constant coefficient. For the glass which he employed, M. Biot has found $m$ equal to $\frac{11}{7}$; by which quantity,

therefore, all observations of the violet blue ray are to be multiplied, to reduce them to Biot's red ray. By very exact determinations, M. Biot finds for cane sugar $c = 1.4$, and $c' = 1.827$. So that

$$\varepsilon\,\delta = 1.4\,\frac{a}{l}, \text{ for the violet blue ray; and}$$

$$\varepsilon\,\delta = 1.827\,\frac{a'}{l}, \text{ for the red oxide of copper glass.}$$

9. One of the applications of this method is to observe the quantity of diabetic sugar contained in the urine of persons afflicted with the peculiar disease which produces it. Biot finds diabetic sugar given to him by M. Péligot, in 1836, identical with that presented by the same person in 1840, and also another specimen obtained from M. Bouchardat, and gives for diabetic sugar the formulæ

For the violet blue ray; $\varepsilon\,\delta = 2.176\,\frac{a}{l}$,

For the red ray, $\varepsilon\,\delta = 2.838\,\frac{a'}{l}$,

For minimum intensity of light, $\varepsilon\,\delta = 2.34\,\frac{a''}{l}$.

10. Hitherto, we have supposed the solution to contain only one active ingredient; now, let it contain unknown quantities of crystallizable cane sugar mixed with uncrystallizable sugar, or any other substances, the rotary power of which, if they have any, is not altered by acids, without the application of heat; then may the quantity of crystallizable cane sugar still be readily determined by the use of acids.

M. Biot has found that the stronger acids generally, when introduced cold into solutions of crystallizable cane sugar, invert the polarizing power, or cause them to rotate from right to left, instead of from left to right. And this seems to be a property belonging to cane sugar only. All other sugars remain unchanged under the influence of cold acids. Certain varieties of starch sugar, when boiled for a long time with dilute sulphuric acid, suffer peculiar and sudden losses of rotary power, which, always directed to the right, at last attains a minimum deviation, at which it remains constant.

In the gum of the acacia, we have an example of inversion by sulphuric acid: the rotary power directed from right to left, gradually travels to the right, with the separation of a precipitate. But

neither of these exceptions can be confounded with the inversion by cold acids for cane sugar.

To an aqueous solution of cane sugar add hydrochloric or sulphuric acid, taking care that it be generally diffused, and not allowed to concentrate its action upon small portions of the whole mass, so as to carbonize them. The deviation to the right will diminish, become gradually reversed, and at last attain a maximum to the left, at which it will be constant. With hydrochloric acid, even one-tenth or eleventh, by volume, will effect this maximum deviation in a few hours. One or two days produce no change, but a more prolonged action causes the solution to become yellow; and afterwards the inverted deviation grows weaker, until the mixture ceases to be transparent. For observations of colorless solutions with this acid, M. Biot finds, if we employ the violet blue ray of the transition from dark blue to orange red in the extraordinary image, that the inverted deviation at its maximum is 0.38 of the primitive deviation; each being observed for an equal thickness and state of dilution, or reduced to such by calculation. For sulphuric acid, this ratio is somewhat greater, and amounts to 0.3867. The progress of the inversion also is slower, unless the temperature be raised to 140° Fahr., in which case it attains the maximum of inversion almost instantaneously, and without becoming colored.

Fermentation inverts the rotary power of cane sugar, while the other sugars preserve the direction of their rotary power under its action. Yet Soubeiran has shown that inverted cane sugar rotates to the left only while in the liquid state; by solidification, it regains its direction to the right, and is not afterwards invertible by acids. On the behaviour of cane sugar with acids, under all the various circumstances of temperature, relative quantity, &c., M. Biot has made an extended series of researches; and though it is two years or more since he promised them to the scientific world, they are not yet published.*

To analyze a mixed solution, therefore, observe its primitive deviation; then dilute it with a known volume of hydrochloric acid, and, allowing sufficient time for the inverted deviation to attain its maximum, observe the angle again. The change produced will enable us to deduce the per cent. of cane sugar in the original mixture, as it is due to it only.

11. To obtain a formula for this purpose, let $x$ be the unknown per cent. of cane sugar in each unit by weight of the mixture—for instance, in an ounce or grain—then $p$ ounces will contain $p\,x$ of cane sugar; and $p$ is taken by a delicate balance; mix it then, if necessary, with $e$ ounces of distilled water. Then in this solution the proportion by weight of the primitive mixture is

$$\epsilon = \frac{p}{p+e};$$

* See Comptes Rendus des Séances de l'Acad,. t. xv, pp. 534, 697.

**And the quantity of crystallizable cane sugar is**

$$s' = s\,x = \frac{p\,x}{p+e} \quad \text{- - - - - - - - - - (3).}$$

Denote by $a'$ the primitive deviation for a particular refrangible ray, and by $a''$ the inverted deviation for the same length of tube and state of dilution. Let $-r''$ be the ratio of inversion, so that $a'' = -r''\,a$. For pure crystallizable sugar, this ratio, which we will call $-r'$, is equal to 0.38 when hydrochloric acid is used.

Let S be the portion of the primitive deviation produced by the cane or invertible sugar, and D the remaining portion, produced by the sugar which is not invertible. D is additive to S, or positive, if the uninvertible sugar act to the right; and negative, if to the left; but the calculations show its sign as well as its value. As $a'$ is equal to the sum of S and D; and as the inverted deviation $a''$ is equal to S, changed by inversion to $-r'$ S, plus D remaining constant, we have

$$\left.\begin{aligned} S + D &= a', \\ D - r'\,S &= a'' = -r''\,a'. \end{aligned}\right\} \quad \text{- - - - (4).}$$

Eliminating, we have

$$\left.\begin{aligned} S &= \frac{1+r''}{1+r'}\,a' = a' + \frac{r''-r'}{1+r'}\,a'; \\ D &= -\frac{r''-r'}{1+r'}\,a'. \end{aligned}\right\} \quad \text{- - - (5).}$$

In these equations $r'$ is always in itself positive, because acids invert the primitive deviation of cane sugar. If the inverted deviation of the mixture also passes really to the left, then will $r''$ be likewise essentially positive. But if it remains to the right, and merely weakened, $r''$ will be negative. Observing this rule of the signs, calculation will always give S and D, and the signs of their values will show their directions, to the right, if positive, and to the left, when negative.

Now the deviation S, observed through a tube of the length $l$, is produced by the cane sugar in the solution, of which $\delta$ is the density and $s'$ the proportion by weight. Hence, by equation (1)

$$(a) = \frac{S}{l\,\delta\,s'} = \frac{S}{l\,\delta\,s\,x} \quad \text{- - - (6).}$$

In this equation, $x$ is the only unknown quantity; and, therefore,

$$x = \frac{S}{l\,\delta\,s\,(\alpha)} \quad - - - - - - - (7).$$

Let $(\beta)$ be the rotary power of the primitive mixture, since it produces the deviation $\alpha'$ through the tube $l$, for the density $\delta$ and proportion $s$, we have, by equation (1),

$$(\beta) = \frac{\alpha'}{l\,\delta\,s}; \text{ and therefore, } x = \frac{S\,(\beta)}{(\alpha)\,\alpha'}.$$

To verify this formula, we may apply it to cane sugar alone; for which $D = 0$, and $S = \alpha'$, and all the active matter having the ratio of inversion equal to $-0.38$, we get $r'' = r'$. If, then standard sugar be identical, both in purity and hygrometric condition with that used in the experiment, $(\beta) = (\alpha)$ and $x = 1$; if the former be drier than the latter, then will it also be more active and $(\beta)$ will be less than $(\alpha)$; if less dry, $(\beta)$ will exceed $(\alpha)$. This verification likewise serves to test the delicacy and exactness of the method. The algebraic formulæ for S and D also show that any small errors of observation enter into their values affected by the denominator $1 + r'$, in which $r'$ is necessarily positive, and which therefore exceeds unity.

12. There are several methods of determining angles of deviation; of these, the best is probably that of observing the violet blue ray. From the law according to which the different rays are dispersed, Biot has been able to show that this violet blue tint in the extraordinary image corresponds with the deviation of the simple yellow rays, and that it is also the point of minimum intensity. Hence, the deviations are comparable, as for a simple ray; and the second peculiarity allows the deviation to be observed when the image is too feeble to discern its color. For perfectly colorless solutions, whether transparent or slightly opalescent, this method is therefore accurate, convenient, and adapted to the naked eye. To observe the violet blue ray, turn the analyzing prism about the transmitted ray as an axis; as it revolves, the blue will become more and more dark, until it changes, almost abruptly to orange red; these two colors are separated only by a violet blue or bluish violet; and it is at this momentary transition color that the motion of the prism is arrested. The angle of deviation is then read off upon the graduated limb. The suddenness of this change, and strong contrast of colors on either side, removes all uncertainty arising from peculiarity of eyes in different individuals. From childhood I have been aware of a constitutional defect in my own eye with reference to the perception of certain colors in the spectrum; it seems to be a partial insensibility to red light; and colors

appear to me nearly as described by Mr. Dalton in the Manchester Memoirs. I was therefore apprehensive, before experimenting upon the subject, that I should be unable to determine angles of rotation with accuracy; but I found, by repeated trials, that independent observations of the violet blue ray, made for transparent colorless solutions by my friends Messrs. Booth and Boyé, did not differ from each other, nor from mine, the quarter of a degree, a quantity which in these observations may be disregarded, as it would not produce a personal equation greater than those which usually affect chemical analyses. And I am confident that practice would have enabled us to have reduced even this difference to the tenth of a degree, within which the graduation of the limb would not admit of reading; for our later observations scarcely exceed that amount in variation, and they were made without knowledge of previous readings on the part of the observer. The means of a number of observations would not, perhaps, differ by an appreciable fraction.

The method of minimum intensity is rendered more exact by observing azimuths of disappearance and reappearance of the image; their mean result will not vary appreciably with considerable fluctuations of the light, whether it be that of a candle or the sky. This method I have employed with satisfactory results.

But, for observations of colored solutions, no method is, probably, so convenient and accurate as that of using an eye piece of colored glass; and particularly of that kind of glass which is stained with the protoxide of copper, which transmits rays so nearly alike in refrangibility that the eye perceives no sensible difference of shade. The thicker the glass, the simpler the color, and the nearer it approaches the extreme red of the spectrum. But, as the quantity of transmitted light diminishes in proportion to its purity, we soon attain a limit of thickness, beyond which the intensity becomes too feeble. To determine the suitable degree of thickness, refract the light of a candle through a dispersive prism; then place the glasses to be examined between the eye and the face of emergence, and select those which transmit only a red image. This red, though not rigorously simple, is yet so nearly so that it will be but slightly dispersed, if the angles of deviation be limited to arcs less than a quadrant; and they need not be greater.

To render the observations more exact for the small arc of nonapparition at the point of minimum intensity, observe the azimuths of disappearance and reappearance of the image, and take their mean. The deviation of the violet blue ray is fixed in nature; but observations of the red ray will vary with the glass employed; and each observer should therefore determine the coefficient $m$ of the particular glass he uses, by which his researches will be rendered comparable with those of other persons. For this purpose, he may employ a transparent solution of cane sugar; the per centage, the density, and the length of the tube, need not be known; but the angles of deviation for the violet blue and the red ray of his glass must be observed repeatedly, and with the utmost care; the mean determinations will give $m$, the coefficient sought. Although the red oxide of copper glass is the only kind yet known, for a slight

thickness, to transmit homogeneous light, green glasses, stained with oxide of chrome, and some of an orange color, when of somewhat greater thickness, may be substituted; for observations of organic solutions of an orange color, an orange glass is very well adapted. I have to regret that I have not yet been able to procure an oxide of copper glass; and the green, blue, yellow, and orange glasses, of which I have tried a large number, when examined by means of a dispersive prism, have proved to be very deficient in their power to transmit homogeneous light without great loss of intensity. But little colored glass is manufactured in this country, and scarcely any into forms which would answer for these experiments.

There is still another method, that by comparison of color, adopted at the suggestion of Marchand, and highly recommended by Ventzke,* through a tube containing an aqueous solution of anilate of iron, and transmitting orange red light, observe the same luminous body which is viewed through the rotating solution; when the colors are of the same tone, read off the corresponding angle. Whatever may be the cause, I have hitherto found it wholly impracticable to arrive at accurate results by this method; nor do I think it owing solely to the defect in my eye, above mentioned; for, though Messrs. Booth and Boyé did not often vary more than one or two degrees, yet sometimes they differed five or more. And a scientific friend, who has no peculiarity of eye with regard to color, and great experience and skill as an observer, varied even ten degrees in his readings for the same solution. It is very difficult to render the light of equal intensity in the two tubes; and the anilate of iron seems to undergo decomposition, as a precipitate separates in the tube. Of this method, therefore, I hesitate to decide, or pronounce any opinion, without giving it another and a fairer trial.

13. Those who would pursue researches in Optical Chemistry must make themselves thoroughly acquainted with the details and principles of construction of the apparatus employed. These they will find fully and clearly developed, together with all necessary information respecting manipulations, in the papers of Biot, to which I refer.† For more general information, I will now endeavor briefly to describe his apparatus, as well as that of Ventzke, which I have used; and to which, from comparison with an instrument of M. Biot, of very superior workmanship, made, I believe, by M. Soleil, of Paris, for J. S. Lovering & Co., of Philadelphia, I give a decided preference. The apparatus I used was imported, with a similar one for their own use, by Messrs. Booth and Boyé, and was made by Maywald, in Berlin; the workmanship appears to be excellent. It is also accompanied by two hydrometers for taking densities, and a thermometer, by J. G. Greiner, of Berlin; which are of remarkable delicacy and beauty.

* See Journal für Praktische Chemie, vol. xxv.

† See, particularly, Am. de Chim. et de Phys., t. 64, p. 401; also, Comptes Rendus, 7. Septem., 1840.

The apparatus of M. Biot is very simple; it consists essentially of a polished black glass plate A, to reflect the light at the angle of Malus (see Fig. 1) of a tube suitably inclined to receive the polarized ray and contain the liquid B; and a prism of Iceland spar, achromatized by removing a portion of the crystal and substituting glass in its place, and attached at the centre of a graduated limb to an alidade C, in such a manner as to be susceptible of adjustment in azimuth. The whole is firmly attached to proper supports. The observer should place himself in a dark room, to render his eye more sensible to delicate impressions, and shut out all light except that which passes through the tube.

The apparatus of Ventzke is not much more complicated, and is composed of two doubly refracting prisms of Iceland spar, (see Fig. 2,) an analyzing prism A, fixed, as M. Biot's, to a movable alidade at the centre of a graduated limb, and a polarizing prism B, of which, by motion about the ray as an axis, the principal section may be nicely adjusted by a tangent screw C, to a position at right angles to that of B, when the index points to zero upon the limb, and the intensity of the ordinary ray becomes $i \cos.^2 x = i \cos.^2 90° = 0$, or perfectly dark. The intense light of the sun's direct ray is used to fix this zero point. Between these prisms the tube D is placed, which contains the solution; and its ends are closed with glass discs. The light employed is that of an argand lamp. The doubly refracting crystals are Nichol's prisms; they are made by grinding the rhombohedron of calcareous spar until its terminal planes form angles of 68° with its obtuse lateral edges. It is then cut diagonally and at right angles to the new planes. The crystal so divided is joined together again by Canada balsam, whose index of refraction, 1.55, lies between that of the ordinary ray, 1.65, and that of the extraordinary ray, 1.48, and operates upon the two rays in opposite directions, separating them so widely that the extraordinary image may be made to disappear. The polarization by this prism is much more complete than by reflexion, and the light is much more intense; the limited field of vision is the only objection. Ventzke's apparatus is far more compact and transportable than Biot's, and is therefore much more convenient for general use. To adapt it to the wants of practical men, refiners, planters, and others, and avoid all calculations, Ventzke has computed tables, and attached to the graduated limb a pinion which turns a wheel fastened to the analyzing prism and the alidade. Upon a disc A. (Fig. 3,) firmly united with the pinion, the per centage is read off directly for solutions of the normal density of 1.1056 at 63½° Fahrenheit, and with tubes of the normal length of 234 millimetres. By means of his tables, densities observed at other degrees of the thermometer may be reduced to the normal temperature.

As Ventzke has not given the calculations and experiments upon which he bases his tables, I prefer to employ the method and formulæ of M. Biot, even though they involve some calculation.

In the thirteenth volume of the Memoires de l'Académie, M. Biot gives a table for solutions of cane sugar, which I annex, (see table

3;) but I prefer to use his formulæ, as that table was constructed with data taken from his earlier and less exact determinations.

*Analysis of several specimens of molasses by the circular polarization of light.*

14. To take the specific gravities of these substances, I found none of the usual methods for liquids well adapted; in several of them there were considerable deposites of sugar or other solid matter; to arrive at mean results, these deposites had to be stirred up from the bottom, and mixed intimately with the fluid portion, so as to form a homogeneous mass. In doing this, a large number of small bubbles of air become entangled in the viscid mixture, which will not all escape until it has stood quietly for twenty-four hours. The use of the *pèse sirop* of Baumé is, therefore, impossible, for it would either be effected by the bubbles of air, or give no indications for the solid matter. A specific gravity bottle was found objectionable on account of the impracticability of removing air bubbles from the neck. I found a surgeon's cupping glass, ground so as to fit tightly upon a small disc of plate glass, to answer every purpose. It could be filled perfectly with water or molasses, and even washed and wiped with a towel until dry, if carefully done, without loss or accident; and the glass disc would, of itself, adhere so closely as to render it liable to no risk of slipping while upon the balance.

The cup and disc were found to weigh 1107.8 grains; filled with water, it weighed 2328.7 grains.

Therefore, 1220.9 grains is the weight of the water alone; log. 1220.9=3.0866801, which is the constant logarithm to be substracted from that of the weight of an equal volume of each specimen. The accompanying table contains the data and corresponding results:

| Molasses. | Weight in grains. $\gamma$. | Log. $\gamma$. | Difference of logs. | Specific gravity. |
|---|---|---|---|---|
| No. | | | | |
| 1 | 1713.2 | 3.2338081 | 0.1471280 | 1.4032 |
| 2 | 1703.6 | 3.2313676 | 0.1446875 | 1.3953 |
| 3 | 1674.8 | 3 2239630 | 0.1372829 | 1.37176 |
| 4 | 1661. | 3.2205003 | 0.1348202 | 1.36089 |
| 5 | 1710.8 | 3.2331992 | 0.1465191 | 1.40126 |

15. The following are determinations by Ventzke's tables for the quantity of water, obtained by observing the densities of solutions composed of three parts by weight of molasses, and seven of water:

| Molasses. | Specific gravity of aq. solution. | Temperat. centigrade. | Per cent. of water. | Per cent. of solid matter. |
|---|---|---|---|---|
| No. | | ° | | |
| 1 | 1.1014 | 15 | 20.32 | 79.68 |
| 2 | 1.0985 | 17.3 | 22.04 | 77.96 |
| 3 | 1.094 | 20 | 24.9 | 75.1 |
| 4 | 1.088 | 15 | 30.5 | 69.5 |
| 5 | 1.100 | 12 | 21.7 | 78.3 |

The specific gravities were taken by a hydrometer made by J. J. Greiner. The fifth column is obtained from the fourth, to which it is complementary.

The analyses by Ventzke's tables, if we use the observed angles of deviation for the anilate of iron, would therefore be:

| Molasses. | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. |
|---|---|---|---|---|---|
| Cane sugar | 57.37 | 51.14 | 50.67 | 45.17 | 59.9 |
| Liquid sugar | 22.31 | 26.82 | 24.43 | 24.33 | 18.4 |
| Water - | 20.32 | 22.04 | 24.90 | 30.50 | 21.7 |

The angles are those of the following data.

16. Equal parts by weight of molasses and water were filtered through bone black, contained in displacement tubes of lengths varying from one to three feet, until perfectly decolorized; by adding water, the colorless solutions were brought to the normal density 1.1056 at 63½° Fahrenheit; they were then observed through tubes of the normal length of 234 millimetres, with the results of the table:

| Observer. | Booth. | Boyé. | McCulloh. | Means. | Booth. | Boyé. | McCulloh. | Means. |
|---|---|---|---|---|---|---|---|---|
| Molasses. No. | Violet ray. | Violet ray. | Violet ray. | | Anilate of iron. | Anilate of iron. | Anilate of iron. | |
| 1 | 24.5 | 24.25 | 24.5 | 24.41 | 74.? | 68.? | 74? | 72? |
| 2 | .... | 25.83 | 25.75 | 25.79 | .... | 66. | 65? | 65.5 |
| 3 | 23. | 23. | 23. | 23. | 69 | 68.5 | 69? | 68.8 |
| 4 | 24.25 | 24.75 | 25.5 | 25.5 | 66 | 64. | ? | 65. |
| 5 | 28.20 | 28.25 | 28.15 | 28.15 | 76 | 77. | ? | 76.5 |

17. To compare the results of these different methods, I formed a solution containing 25 per cent. by weight of pure crystallized cane sugar, and found it of the normal density. This solution (Ventzke's

normal solution) should read for the anilate of iron 56° or on the pinion disc 100 per cent.; which I found to be the case for the eyes of Messrs. Booth and Boyé, as well as for my own. The violet ray was observed by Mr. Boyé and myself, with the same result, 42° or 75 per cent. on the disc. The coefficient by which we must multiply the means of the violet ray, to reduce them to those of the anilate of iron ray, is therefore $\frac{100}{75}$. The following table gives the comparison:

| No. | Violet. | Violet reduced. | Per cent. by anilate of iron ray. | | |
|---|---|---|---|---|---|
| | $a$ | $\frac{100}{75} a$ | Calculated. | Observed. | Difference. |
| | ° | ° | | | |
| 1 | 24.41 | 32.55 | 58. | 72. | 14. |
| 2 | 25.79 | 34.38 | 61.75 | 65.5 | 3.75 |
| 3 | 23. | 30.66 | 55. | 68.8 | 13.8 |
| 4 | 25.5 | 34. | 61. | 65. | 4. |
| 5 | 28.15 | 37.53 | 67. | 76.5 | 9.5 |

The differences in the last column of this table are so large that they establish the fact that no accuracy can be attributed to the observations made with the solution of anilate of iron employed in these experiments. The following analyses, obtained from the *calculated* per cents of the preceding table, are more entitled to credit, as they depend upon the accordant observations of the violet ray:

| Molasses. | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. |
|---|---|---|---|---|---|
| Cane sugar - | 46.21 | 48.21 | 40.50 | 42.39 | 52.46 |
| Liquid sugar - | 33.47 | 29.75 | 34.60 | 27.11 | 25.84 |
| Water - - - | 20.32 | 22.04 | 24.90 | 30.50 | 21.70 |
| Total - | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

18. These results seem to agree with certain analyses of Biot and Soubeiran. In good sugar-house molasses, Biot has found 40 per cent. of crystallizable cane sugar; while Soubeiran, from many specimens, gives as the amount of cane sugar in molasses 50 per cent., after deducting the water. If we compute the water at 20 per cent., then we will have 40 per cent. as the proportion; and this is the result of M. Biot. Ventzke has found as much as 60 per cent. by the use of the comparison tube of anilate of iron.

It is extremely difficult to render aqueous solutions of molasses perfectly colorless by the use of bone black; there is a yellow tint, which in some cases, it seems almost impossible to remove, and which, when viewed through a tube 234 millimetres in length,

is sufficiently deep to affect very materially any results by comparison of color. The bone black I employed was of very superior quality. Yet several of my solutions, though filtered five or six times through thicknesses of two or three feet of fresh bone black, obstinately refused to part with the yellow tint above mentioned.

The specimens of molasses, which I have called Nos. 1, 2, 3, 4, and 5, were taken by the officers of the customs for the port of Philadelphia from cargoes imported into that city from the West Indies, in June or July, 1843, in compliance with the circular of the Secretary of the Treasury of 12th May, 1843. They had remained since that time in loosely stopped bottles, which stood in a dry place. That water had evaporated from them to a considerable extent, is shown by the fact that their specific gravities exceed those determined in July, 1843, by Messrs. Booth and Boyé for specimens just imported. This also renders my results, as given in the last table, nearly accordant with those of Biot and Soubeiran. What had been the effects of atmospheric fluctuations of temperature in causing fermentation during the year which has elapsed since the molasses was imported it is impossible to conjecture. When No. 2 was removed to a room heated by a stove, and allowed to stand on a shelf for several days, fermentation commenced, and the carbonic acid forced the cork from the bottle. On removing it to a colder room, this fermentation ceased. In it there was also a deposite of solid sugar, which constituted one-sixth by volume of the whole. In taste, it was slightly acid. Of No. 1, the taste was a pure sweet, very mild and rich; it contained no deposite; it is the same as No. 13 of the analyses of Messrs. Booth and Boyé. No. 3 contained no deposite, and was very acid to the taste. No. 4 likewise contained no deposite, and was very acid in taste. In No. 5 there was a deposite of one-fifteenth of the whole volume; its taste, at first purely sweet, acquired an acid flavor in the mouth.

19. I shall now apply to the qualitative analysis of these specimens of molasses the formulæ and process of inversion by acids of M. Biot. To this end, I employ the solutions of article 16, and hydrochloric acid of the specific gravity of 1. 18, in volumes which I calculate from their weights and densities, by means of the well known formula $w = d\,v$. Biot measures these volumes directly, by means of the tubes of M. Gay Lussac. The use of the balance is more exact. I mixed them in quantities which weighed, in grains:

| | No. 2. | No. 3. | No. 4. | No. 5. | Density. |
|---|---|---|---|---|---|
| Solution . | 219 | 281.9 | 218 | 299.3 | 1.1056 |
| Acid . | 41.5 | 59.2 | 36.1 | 49.8 | * 1.18 |

The logarithmic calculations are as follows: Let $W = D\,V$ be the equation of volume for the saccharine solution, and $w = d\,v$ the corresponding equation for the acid; in which W and $w$ are the

weights of the table, D and $d$ the densities, and V, $v$ the unknown volumes to be calculated.

Then, for No. 2, we have

| | | | |
|---|---|---|---|
| log. W | 2.3404441 | log. $w$ | 1.6180481 |
| log. D | 0.0435980 | log. $d$ | 0.0718820 |
| log. V | 2.2968461 | log. $v$ = | 1.5461660 |
| $\therefore$ V = | 198.0825; | $\therefore$ $v$ = | 35.1695; |
| | V + $v$ = 233.2520. | | |

For No. 3, we obtain

| | | | |
|---|---|---|---|
| log. W | 2.4500951 | log. $w$ | 1.7723217 |
| log. D | 0.0435980 | log. $d$ | 0.0718820 |
| log. V | 2.4064971 | log. $v$ | 1.7004397 |
| $\therefore$ V = | 254.9741; | $\therefore$ $v$ = | 50.1695; |
| | V + $v$ = 305.1436. | | |

And for No. 4,

| | | | |
|---|---|---|---|
| log. W | 2.3384564 | log. $w$ | 1.5575072 |
| log. D | 0.0435980 | log. $d$ | 0.0718820 |
| log. V | 2.2948584 | log. $v$ | 1.4856252 |
| $\therefore$ V | 197.17804; | $\therefore$ $v$ = | 30.5932. |
| | V + $v$ = 227.77124. | | |

Lastly, for No. 5, we have

| | | | |
|---|---|---|---|
| log. W | 2.4761067 | log. $w$ | 1.6972293 |
| log. D | 0.0435980 | log. $d$ | 0.0718820 |
| log. V | 2.4325087 | log. $v$ | 1.6253473 |
| $\therefore$ V = | 270.71275; | $\therefore$ $v$ = | 42.233; |
| | V + $v$ = 312.94575. | | |

From these volumes we compute the *ratio of dilution*, which is equal to $\frac{V}{V+v}$, and is the coefficient by which we must multiply the observed angles of the violet ray of art. 16, to reduce them to the proper state of dilution. I give the calculations by means of logarithms.

For No. 2,

| | | | |
|---|---|---|---|
| log. V | 2.2968461 | log. (violet) | 1.4114792 |
| (log. V + $v$) | 2.3678254 | | 1.9290207 |
| | 1.9290207 | log. $a'$ | 1.3405000 |
| = log. | 0.8492. | $\therefore$ $a'$ = | 21°.9028. |

For No. 3,

| | | | |
|---|---|---|---|
| log. V | 2.4064971 | log. (violet) | 1.3617278 |
| log. (V + $v$) | 2.4845042 | | 1.9219929 |
| | 1.9219929 | log. $a'$ | 1.2837207 |
| = log. | 0.8355871. | $\therefore a'$ = | 19°.2185. |

For No. 4,

| | | | |
|---|---|---|---|
| log. V | 2.2948584 | log. (violet) | 1.3891661 |
| log. (V + $v$) | 2.3574984 | | 1.9373600 |
| | 1.9373600 | log. $a'$ | 1.3265261 |
| = log. | 0.86569. | $\therefore a'$ = | 21°.2093. |

For No. 5,

| | | | |
|---|---|---|---|
| log. V | 2.4325087 | log. (violet) | 1.4494784 |
| log. (V + $v$) | 2.4954855 | | 1.9370232 |
| | 1.9370232 | log. $a'$ | 1.3865016 |
| = log. | 0.865014. | $\therefore a'$ = | 24°.35. |

20. Having obtained the values of $a'$, the angle of deviation reduced to the same state of dilution as the acidulated mixture, and as it would have been observed by adding water alone, we next proceed to determine $a''$ the angle of deviation of the violet ray for the acid solutions. This is done by direct observation. On account of the color developed by the action of the acid upon the saccharine solution, I was compelled to use the method of minimum intensity and mean observations of angles of disappearance and reappearance of the image, except for No. 2, to which the acid had given only a slight yellowish tinge, which did not enfeeble the light sufficiently to obscure the violet ray.

The readings for No. 2 were 12° to the left, and then again 12°.25, of which 12°, 125 = $a''$ is the mean.

| No. and color after inversion. | No. 3. Orange. | | | No. 4. Orange. | | | No. 5. Orange. | | |
|---|---|---|---|---|---|---|---|---|---|
| Azimuths. | Disappearance. m. | Reappearance. n. | Sum of (m + n.) | Disappearance. m. | Reappearance. n. | Sum of (m + n.) | Disappearance. m. | Reappearance. n. | Sum of (m + n. |
| | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| | —4. | —16. | 20. | —3.5 | —17. | 20.5 | —5.5 | —12.5 | 18. |
| | 7. | 13.75 | 20.75 | 6. | 19. | 25. | 6.5 | 12.5 | 19. |
| | 2.5 | 15.5 | 18. | 7. | 15.5 | 22.5 | 6.25 | 12.25 | 18.5 |
| | 4.25 | 14.5 | 18.75 | 6.5 | 16.5 | 23. | 8.5 | 15.5 | 24. |
| | 5.5 | 15.5 | 21. | 6.5 | 15.5 | 22. | 7.5 | 16. | 23.5 |
| $a''$= | Mean, —9°.85. | | | Mean, — 11°.3. | | | Mean, —10°.3. | | |

21. To obtain $r''$ *the ratio of inversion*, we divide $a''$ by $a'$ for the four mixtures; this calculation is as follows:

| For No. 2, | | For No. 3, | |
|---|---|---|---|
| log. $a''$ | 1.0836817 | log. $a''$ | 0.9934362 |
| log. $a'$ | 1.3405000 | log. $a'$ | 1.2837207 |
| log. $r''$ | $\overline{1}$.7431817 | log. $r''$ | $\overline{1}$.7097155 |
| $\therefore r'' =$ | 0.5536. | $\therefore r'' =$ | 0.5125. |

| For No. 4, | | For No. 5, | |
|---|---|---|---|
| log. $a''$ | 1.0530784 | log. $a''$ | 1.0128372 |
| log. $a'$ | 1.3265261 | log. $a'$ | 1.3865016 |
| log. $r''$ | $\overline{1}$.7265523 | log. $r''$ | $\overline{1}$.6263356 |
| $\therefore r'' =$ | 0.5128. | $\therefore r'' =$ | 0.423. |

22. Now, by equation (5) of art. 11, it appears that

$$S = \frac{1+r''}{1+r'} a'; \text{ and } D = a' - S.$$

That in these formulas each quantity might be obtained from my own observations, independently of those of others, I determined, by experiment upon a solution of pure cane sugar directly and by

inversion, for $r'$, the value 0.376, a result which differs from that of M. Biot, 0.38, only by 0.004, but by which quantity nearly my experiments were probably in error; for, as they were instituted only to confirm or disprove the coefficient of M. Biot, they were performed hastily, and without that extreme care which should always be bestowed on the determination of the constants of physical phenomena. Sufficient time, also, was not allowed to permit the inverted deviation to obtain its maximum. I shall therefore adopt the value 0.38 as the most probable coefficient.

The calculations for S and D, are:

| For No. 2, | | For No. 3, | |
|---|---|---|---|
| log. $1 + r''$ | 0.1913392 | log. $1 + r''$ | 0.1796954 |
| log. $a'$ | 1.3405000 | log. $a'$ | 1.2837207 |
| arith. co. log. $1 + r'$ | 9.8601209 | log. $1 + r'$ arith. co. | 9.8601209 |
| | 1.3919601 | | 1.3235370 |
| $\therefore$ S = | 24.°6581; | $\therefore$ S = | 21°.064; |
| $a' -$ S = D = — | 2°.7553. | D = — | 1°.8455. |

| For No. 4, | | For No. 5, | |
|---|---|---|---|
| log. $1 + r''$ | 0.1797815 | log. $1 + r''$ | 0.1532049 |
| log. $a'$ | 1.3265261 | log. $a'$ | 1.3865016 |
| log. $1 + r'$ arith. co. | 9.8601209 | log. $1 + r'$ | 9.8601209 |
| | 1.3664285 | | 1.3998274 |
| $\therefore$ S = | 23.°2502; | $\therefore$ S = | 25°.109; |
| D = — | 2°.0409. | D = — | 0.759. |

Hence the angles of deviation $a'$ are caused by a quantity of cane sugar, which, for the state of dilution $\frac{V}{V+v}$ and the normal length 234 millim., produces a rotation equal to S, together with other active substances having a combined rotation of D *to the left*, but which may and probably does consist of a mixture of different uninvertible sugars, polarizing in opposite directions.

—

*General practical remarks.*

23. Although both Biot and Soubeiran have given 40 per cent. as the proportion of cane sugar in sugar-house molasses, while Ventzke estimated it at 60 per cent., it should be borne in mind that West India molasses is a very different article from the molasses of sugar refiners. The first results from an imperfect extraction of brown sugar, performed upon the plantations usually in great haste. It is the mother liquor of the first crystallization. The second has undergone two successive evaporations and crystallizations: the first to obtain the loaf and lump sugar; and the second, for the bastard. It should therefore contain less of cane sugar.

If we compare West India molasses with the drippings from the loaves of refined sugar, the analyses will appear in deficiency, instead of being in excess; for M. Biot found a specimen of such drippings to contain 70 per cent. of cane sugar. It may also be affirmed, for reasons which I will presently state, that, unless the solubility of cane sugar is greatly impaired by the presence of foreign substances, good molasses must contain at least 60 per cent. when first manufactured. Though Ventzke gives 60 per cent. for the proportion of cane sugar in sugar-house molasses, I am strongly persuaded that any analyses made by his method, whether the angles of deviation be exactly determined or not, possess no title to credit; for I concur with Hochstetter* in believing that Ventzke's experiment, from which he inferred that liquid cane sugar or molasses sugar, possesses no rotary power, serves only to show that prolonged boiling may produce a neutral mixture of materials rotating equally in opposite directions. And even should fresh sugar-house molasses be converted, by boiling, into molecularly inactive liquid sugar, the negative values I have obtained for D, show that West India molasses contains left polarizing liquid sugar, which must affect determinations by Ventzke's method by neutralizing the action of a portion of the cane sugar, and rendering the per cent. obtained deficient to an amount corresponding to a deviation equal to D to the right. Nor do I know any method of determining the relative quantities of cane sugar, and left polarizing sugar, except that of inversion by acids. That left polarizing sugar exists in West India molasses, follows from the fact that fermentation takes place; which, as already stated, occurred in No. 2, when removed to a warmer room, and forced the cork out of the bottle by the carbonic acid evolved.

24. The report of Messrs. Booth and Boyé to the collector of the port of Philadelphia (hereto annexed, and marked A) sets forth a remarkable and important fact, which, if the value of molasses depends upon the quantity of cane sugar it contains, renders the mode of levying duty by weight, as established by the present tariff, entirely in error. The fact to which I allude is, that molasses contains more crystallizable cane sugar, and less of mucilaginous or liquid sugar, in proportion as a given bulk of it weighs less; and this fact is confirmed by my own analyses.

25. However different the quantities of crystallizable or cane sugar given by Messrs. Booth and Boyé and by myself may at first appear, they are still in strict accordance; for while the numbers of my table express the absolute or entire quantity of cane sugar in 100 parts by weight of molasses, the fourth horizontal column of the table of Messrs. Booth and Boyé gives only that proportion of the whole amount of cane sugar which crystallizes out of a saturated mother liquor, still retaining probably 66 per cent. of its own weight of cane sugar in solution. The Matanzas syrup (No. 15) was used as a standard of comparison, and the 43.65 per cent. of cane sugar of the fourth horizontal column is the relative quantity

*See Journal für Praktische Chemie, vol. 27; also, Franklin Institute Journal, 1843.

which will crystallize out of it as a mother liquor. From which result Messrs. Booth and Boyé calculate the other numbers of that column, by proportion, from the absolute quantities obtained, which are not given in the table of their report. Now, a saturated solution at 212° Fahrenheit will contain about 80 per cent. of cane sugar; and of this 80 per cent. 50 will crystallize. A very simple proportion gives, therefore, 64 per cent. as the absolute amount corresponding to a yield of 40, by direct crystallization.

26. A series of exact chemical researches, having for their object the determination of the substances, whether vegetable or mineral, composing the cane, and with a view to furnish methods of preventing their injurious effects, could not fail to be of great value. On this subject much remains to be done; and to the planters of the United States, who have to contend with all the disadvantages of a more northern climate, against the competition of their more favored island neighbors, would such knowledge be particularly valuable. In illustration, I am told that there is often contained in Louisiana cane juice a large quantity of a substance like jelly. It prevents the proper defecation by lime, and will even clog the channel which conducts the juice from the mill, if lumps of chalk or lime be placed therein; it also precludes the use of bone black. Now, it does not appear to be either albumen or pectine; yet it interferes greatly with the manufacture of sugar, and therefore to understand its nature is of great importance.

By the researches of M. Hervy it appears to be established that cane sugar is a primary secretion of the plant, and that it does not mature, like the sugar of fruit, from pulpy matter, but is contained alike in the old and new knots—in both of which the same simple structure appears—microscopic observation showing no difference for the different stages of vegetation, the same tubes, bundles of fibres, &c., appearing in all. In fruits, however, M. Frémy has shown that the cellules change from day to day. As they approach maturity, their thick walls, which at first are almost opaque, grow transparent, swell up and burst, discharging their acid contents. The action of this acid upon the ligneous matter may convert it into sugar, as starch and woody fibre are changed into a species of sugar by dilute sulphuric acid. Hence the reason that grape sugar may be produced artificially, while cane sugar appears beyond our power of manufacture. Now, it follows from this fact, and the direct experiments of M. Hervy, that crystallizable cane sugar is the only saccharine matter in the cane,* and that all the molasses sugar, grape sugar, &c., contained in molasses, are results of decomposition of cane sugar by imperfect management. Certainly, then, too much importance cannot be attached by the planter to a knowledge of the causes, and their remedies, which produce this decomposition. When beets grow in land too highly manured, or containing soluble salts, their juice is very difficult to crystallize, and yields

* See Journal de Pharmacie, t. xxvii.; Janv., 1841.

a large quantity of molasses. So canes, grown upon soils where timber has been recently burned, take up the soluble salts by their roots, which must act very injuriously. Common salt will form a compound with six times its weight of sugar, which refuses to crystallize, and remains in the mother liquor; so likewise alkaline carbonates, and other salts, operate to increase the quantity of molasses, and injure the quality of the sugar.

27. The assertion I have made, that a solution containing 80 per cent. at 212° Fahrenheit will permit 50 only to crystallize, is based upon the following facts and experiments. In nearly all the elementary works on chemistry, it is erroneously stated that sugar "dissolves in hot water to any extent." The error seems to be copied from book to book, without even a change of language. At my request Mr. Hewston, an assistant in the laboratory of Messrs. Booth and Boyé, performed the following experiment: 120 grains of pure cane sugar were treated at 212° Fahrenheit, with 20 grains of water, for one hour, and left 36.4 grains undissolved. It is true, therefore, as M. Dubrunfaut has stated, that water at 212° will not take up more than five times its own weight of crystallizable sugar, of which it parts with three by crystallization on cooling. This fact is confirmed by M. Hervy, and also by Biot's determination of the cane sugar in the drippings from the moulds for loaves, 70 per cent., as well as by my own experiments. Hence a saturated solution at 212° contains, say 16.6 of water, and 83.4 of pure sugar; on cooling it parts with 50 per cent. The mother liquor contains 16.6 of water, and 33.3 of sugar, or 100 parts consists of $66\frac{2}{3}$ per cent. of cane sugar, and $33\frac{1}{3}$ of water.

28. It is not true, as is generally supposed, that the quantity of refined sugar obtained by the vacuum pan is much larger than that of an open boiler. It is true that a sugar of far superior quality and great beauty is produced by the vacuum pan, but in quantity it does not differ much from the yield of the old method. From facts furnished to me by some of the most experienced and intelligent of the refiners of our country, I find that 26,000,000 of pounds of raw sugar, refined by the vacuum process, and without claying, gave the mean product of 55.38 per cent. of loaf sugar; 1,000,000, refined by the old method, yielded 53,57 per cent., of which about 40 only were loaf sugar, and 13.57 lump, or of inferior quality. By the use of the vacuum pan, a very rarified atmosphere of steam is substituted in place of the air, which doubtless prevents to a very great extent, if not entirely, the formation of formic acid, which exerts a most pernicious influence upon the color and crystallization of sugar, and which Hochstetter has shown to be the product of the action of the oxygen of the atmosphere upon the heated sirup. Formic acid is also doubtless produced in large quantity during the operation of claying; for the drops which trickle through expose a very large surface to the action of the air. By allowing them to fall into a vacuum, or into steam, a better bastard sugar might probably be manufactured. In steam, the

oxygen is united with the hydrogen by a very powerful chemical affinity, while the atmospheric air seems to be a mere mechanical mixture of oxygen and nitrogen, so feeble is the chemical force, if there be any, between them. Hence, many substances are far more readily oxidized at the expense of atmospheric air than of steam, and especially those of organic origin; and the one supports combustion, while the other extinguishes it.

29. It has been thought that extensive frauds are practised upon the revenue, by introducing sirup of cane, battery sirup, or saturated solutions of sugar, colored by the addition of a little caramel, and flavored with a portion of genuine molasses; that this fradulent article is purchased by the sugar refiners, who subsequently export the sugar they obtain from it with allowance of drawback; that thus the government is robbed annually of thousands of dollars; and the sugar trade of our southern States deprived of that protection which the tariff is calculated to afford. To what extent frauds of such a nature may have been perpetrated, I am unable to say; and upon this point I have little information besides that contained in the reports made by the collectors of the principal ports, in reply to the circular of the Secretary of the Treasury of May 12, 1843. I therefore beg leave to refer to those reports, and to other papers now on file in the Treasury Department, but which are all embodied in a communication, made to the Senate at the close of the last session. (See Sen. Doc. No. 12, 2d session 28th Cong.) From the knowledge I possess of the nature of the article usually sold as West India molasses, and from the high quality of the standard adopted by the government as refined sugar entitled to drawback, I do not hesitate to say that such sugar cannot, in the present state of the art of sugar refining, possibly be made from molasses, or sirup adulterated with molasses. Those refiners who extract sugar from molasses manufacture only a brown sugar, which contains so much uncrystallizable or mucilaginous sugar as to render it wholly unfit for refining. That from molasses, which usually contains nearly 60 per cent. of crystallizable sugar, and from which 40 per cent. may be actually crystallized, leaving still 20 per cent. in the mother liquor, a refiner may and does extract say 35 per cent., realizing a sufficient profit, is certainly not surprising. And these are facts which are established by the analyses of Messrs. Booth and Boyé and myself; and by the information contained in the report to the Secretary of the Treasury, of the collector of Philadelphia, made 10th August, 1843.

Whether this branch of industry, which is pursued only by a few individuals, and to an extent at present which is trifling in its influence upon the sugar trade, shall be checked before it attains sufficient growth to interfere considerably in the home market with the brown sugars of Louisiana, is a question which I should leave with those upon whom the constitution confers the authority and devolves the duty to determine; with the remark, however, that, so long as planters furnish to the market molasses which, like the specimens Nos. 3 and 4 of my analysis, contains sixty per

cent. of cane sugar, and but a very small relative proportion of foreign matter, it will be found profitable to extract 35 per cent., unless a high relative duty is levied upon molasses. And whether it may be well to increase the tariff upon molasses, or whether the Louisiana planter, who, in competition with the West India trade, has to contend with the disadvantages created by his northern climate, should not receive further protection, is a question which belongs to the legislative department of the government. As a chemist, I, however, do not hesitate to say that sirup may be so disguised as to render it extremely difficult, if not impossible, for even experienced sugar refiners to decide whether it be molasses or not. And I feel confident that I could readily compose a mixture which would deceive both the officers of the customs and refiners by their usual tests of sight, taste and touch, and without rendering it difficult to obtain from it a sugar which would be of very good quality, but which might not yield an article that would be allowed at the custom-houses to receive the benefit of drawback.

Cane sugar may be mechanically mixed with molasses, and fraudulently imported as a deposite in the cask; it would then increase the weight, and could be readily detected by a revenue officer. But it does not follow that molasses, containing even a very considerable deposite, is mixed with sugar; for this deposite may, and often probably does, consist of organic matter, less soluble than sugar.

30. In conclusion, I would state that, by the methods I have described, sugars, sirups, molasses, and other saccharine substances, may be accurately analyzed and distinguished from each other. There is not, to my knowledge, in organic chemistry a test so delicate and decided as the copper test of Trommer, with the exception of that of iodine for starch; and combined chemical and optical analyses seem to possess all requisite accuracy for practical purposes. Already has this beautiful discovery of Biot found its way into refineries; and the house of MM. Say & Duméril, of Paris, have employed it with accuracy and profit. The highly intelligent and enterprising proprietors of the firm of J. S. Lovering & Co., of Philadelphia, have also availed themselves of this process; and in their establishment may be seen practically illustrated, on a large scale, the advantages to be attained by the union of science and art. To put the question entirely at rest, however, of what constitutes molasses, and what syrup, and how one may always be distinguished from the other, as well as to establish the facts by an increased number of examples, which the analyses of a few specimens only, as given by Messrs. Booth and Boyé and myself, tend to show, I deem it expedient that further researches should be made upon this subject. Analyses of cane juice, in its different stages of progress, sirup of cane, battery sirup, &c., should also be made, which can only be properly done before it has suffered change by fermentation or otherwise in its removal from the place of manufacture; which analyses may serve incidentally to show whether

the above mentioned disadvantages of climate, which affect the planters of our country, may not, at least in part, be alleviated by increased knowledge of the composition and properties of the material upon which they operate, and consequent improved processes of manufacture; and thus the government may be put in possession of all the facts necessary to enlighten and illustrate its policy with reference to this subject; frauds, by being rendered of ready detection, will be prevented, and their attempts finally abandoned; and knowledge will be obtained which cannot fail to be of general interest and great importance to all concerned in the manufacture of sugar, whether as planters or refiners. These analyses may be made at but little cost, and, through the instrumentality of the officers of the customs and coöperation of the Treasury Department, the several varieties of molasses imported may be procured, accompanied with information respecting their places of manufacture, and the times and ports at which they were shipped.

*On the drawback to be allowed on foreign sugars refined in the United States.*

31. I have felt much perplexed to devise the proper means of furnishing the evidence called for by the second clause of the resolution of the House of Representatives of July 21st, 1842. Not that it is difficult to decide what amount of drawback should be paid, or to obtain accurate information upon which to base suitable action; but experiments on a small scale will not answer the question, what is the practical economical result of large operations, although they may, and they do, confirm the testimony of those engaged in refining sugar. Such researches as those I have mentioned on the solubility and crystallization of sugar, have, apart from their immediate value, that also of enabling us to sit in judgment upon testimony offered by persons professing an acquaintance with this branch of industry, and whose professions may be, and sometimes are, rather the fruit of boastful ignorance than of accurate knowledge. I have been struck with the discordance of statements which have been made by individuals, whose characters are beyond impeachment, and who doubtless all believed what they represented. But many of them testify from hearsay; hence it is natural that the government should have been greatly at a loss what to believe, or what decisions to consider just.

The present refiners themselves, who only can testify from knowledge, have been regarded as interested witnesses; and old refiners who have retired from the business, when they make statements with regard to recent improvements, usually speak from conjecture, and often imagine the results to be far beyond the actual facts. If we would resort to books for information we are equally liable to be misled; for those books are generally the productions of foreign authors, who speak for their own countries; and it is a fact highly creditable to our countrymen that American refined sugar, of superior quality, surpasses in excellence and beauty any that is made in Europe, and that it therefore commands a higher price in foreign

markets. But refining may be considered a separation of the impurities from raw sugar; and, if we would obtain a better article, we cannot therefore produce so much of it.

I have come to the conclusion, that whatever may be the confirmatory experiments we may try on a small scale, the desired information can only be satisfactorily reached by recourse to the principal establishments themselves. But it would neither be proper to demand nor fit that the refiners should expose to the public private affairs upon which their success as individuals may often depend. Our government very properly protects the private interests of her citizens in the fruits of their mental labor by patent rights; but there are advantages that some manufacturers possess over their competitors, which can only be properly secured by keeping them secret; and it is certainly no want of liberality that persons should reap the fruits of their own experience, often bought at the expense of heavy losses of capital. I make these remarks because the refiners have been blamed for their secrecy; but those who have visited manufacturing establishments are aware that sugar refiners are not singular in keeping their secrets. I have not found them more so than others, and a proper personal introduction has never failed to open even the most hidden mysteries to me, yet in confidence that I would not divulge private matters, to the disadvantage of those who extended to me facilities of accurate information. It is from knowledge thus obtained from refiners of high standing and intelligence, as well as from my own personal observations of their processes, that I give the following as the probable average yield of refining in the United States. Thirty per cent. of white sugar and seventy per cent. of brown (the average mixture) yield—

| By the vacuum process : | | By the old process : | |
|---|---|---|---|
| Refined..... | 55.4 | Loaf..... | 40. |
| Bastard ..... | 22.9 | Lump ..... | 13.6 |
| Molasses ..... | 17.4 | Bastard. ..... | 19.6 |
| Dirt and waste..... | 4.3 | Molasses ..... | 24.5 |
| | | Dirt and waste..... | 2.3 |
| | 100.0 | | 100.0 |

These are the mean results, not of a particular variety of raw sugar, nor for a single year, but of millions of pounds, and of refining with great intelligence and skill. I calculate from them the drawback to be allowed as follows:

| | |
|---|---|
| Duty on 30 pounds white, at 4 cents..... | $1.20.00 |
| Duty on 70 pounds brown, at 2½ cents..... | 1.75.00 |
| | 2.95.00 |

| | | |
|---|---|---|
| For the vacuum process: | | |
| Duty to be retained on 22.9 pounds bastard, or brown, at 2½ cents | $0.57.25 | |
| 17.4 pounds molasses, at 4½ mills | 0.07.82 | |
| | | $0.65.07 |
| | | 2.29.93 |
| Drawback 4.15 cents per pound on 55.4 refined | | 2.29.91 |
| Difference in favor of the revenue | | 0.00.02 |
| For the old process: | | |
| Amount of duty, as above | | $2.95.00 |
| 19.6 pounds, at 2½ cents | $0.49.00 | |
| 24.5 pounds, at 4½ mills | 0.11.02 | |
| | | 60.02 |
| | | 2.34.98 |
| Drawback 4.4 cents on 53.6 pounds | | 2.35.84 |
| Difference in favor of the refiner | | 0.00.86 |

The mean, 4.27 cents, or 4¼ nearly, would therefore be the fair average drawback to be paid on refined sugar, under the present tariff.

Preliminary to the inquiry, what is the amount of drawback to be allowed on refined sugar, is the question: what is "*refined sugar*" itself? The present tariff act, section 14, enacts, that "there shall be allowed a drawback on foreign sugar refined in the United States, and exported therefrom, equal in amount to the duty paid on the foreign sugar from which it shall be manufactured, to be ascertained by such regulations as shall be prescribed by the Secretary of the Treasury, and no more." Now, the question, *what is refined sugar under the meaning of the laws of the United States?* is fortunately not open to difference of opinion, although various countries have adopted different definitions, in conformity with their respective policies. In Great Britain, for instance, refined sugar is considered to be the whole product including even the darkest bastard; and this explains the fact, that the refiners of that country are required to export 67 per cent. when refining in bond. But by the decision of the Supreme Court in the case of Barlow *vs.* the United States, 7 Peters, 410, it is established, that "if, in a loose signification among refiners, sugars should sometimes be spoken of as being refined, without having undergone the further process of claying, or if the whole mass resulting from that process should sometimes indiscriminately acquire among them that appellation in a like loose signification, still if among buyers and sellers generally, in the course of trade and business, the appellation 'refined sugars' is exclusively limited to the products called lump and loaf sugar, and never includes bastard sugar, the acts of Congress ought to be construed in this restrictive sense. This was the doctrine of this court in the case of two hundred chests of tea, Smith,

claimant, 9 Wheaton's Reports, 438, 439; and there is not the slightest inclination on the part of this court to retract it. Now, without minutely sifting the evidence in this case we think that there is a decisive and unequivocal preponderance of evidence to establish that bastard sugar is not deemed in a commercial sense 'refined sugar.' The appellation is *exclusively limited to such as have assumed at some time the form of white refined loaf or lump sugar.* This is established, not merely by the testimony of merchants and grocers, and persons in the custom-houses, but by the testimony of sugar refiners."

Hence, of the 53.6 per cent. of refined sugar obtained by the old process, I have not in my calculations discriminated between the 40 per cent. of loaf sugar and 13.6 of lump, but have treated it all alike as refined sugar entitled to drawback. And if, as I have been told, at some of the custom-houses, lump sugar or refined sugar of inferior quality, is not allowed the benefit of drawback, it seems to me that it is in clear violation of the legal rights of the refiner, which entitle him to claim on "refined sugar," of *any* quality, drawback "equal in amount to the duty paid," "and no more." In compliance with the tariff act of 1842, the Secretary of the Treasury took steps to ascertain this "amount of duty paid;" and they are reported in Senate Document No. 12, second session twenty-eighth Congress. Unfortunately for the interest of the refiners, the testimony of persons was relied on who did not testify correctly, and some of them even from conjecture. The yield of the process of refining was assumed to be 75 per cent. of refined sugar, and the drawback was consequently fixed at three and a half cents per pound. Had it been correctly determined, (and that it was not, is the fault of those who offered testimony in the case,) I am of opinion that it would have been of great advantage to the commerce of our country, particularly in the Italian trade; for I am informed that at present much of the sugar refined in Holland and England is imported into the United States, and subsequently exported in Italian vessels, with allowance of drawback, to Italy. This is done for the purpose of obtaining the benefit of the differential duties, which have been established in favor of American produce with a view to the extension of Italian enterprise and the cultivation of commercial relations with the United States. And it is owing to the policy adopted by England and Holland, of allowing not merely drawback, but *bounty*, on refined sugar, that notwithstanding the double freight and commission, and the 10 per cent. of duty retained by our government, the British and Dutch refiners can and do indirectly enjoy, to the exclusion of our citizens, the benefit of regulations which were intended for them alone. I have now before me a letter on this subject from the consul of one of the Italian governments for the city of New York, furnishing evidence of what I have just stated; and I have been told, by very intelligent refiners, that, even with the comparatively high prices of labor which American workmen do *and should always* receive, they can compete with the refiners of Holland and England in Italian markets, if our government will merely return to them the

full amount of duty paid; and that this should be done cannot be doubted, not only because it is but justice to the refiner, but also because it would give employment to a large number of workmen, and greatly serve the commerce of our country.

To put the question of drawback on refined sugars entirely at rest, technical investigations can be made at a slight expense, in a manner which will, I think, furnish at an early day facts that may be published without injury to private persons or violation of confidence, and which will leave nothing to be desired with regard to their completeness or their authenticity.

# SECTION II.

## INTRODUCTION.

32. The arrangement I have adopted in this section is, first, to develope the general theory of hydrometers, with a decimal system for the graduation of their scales; after which, particular instructions will be given for their construction, and the different instruments in use in the United States and in Europe will form so many instances to which the general principles established may be applied. I shall then discuss the present state of our knowledge upon the temperature of the maximum density of water, and apply to the most exact observations a method of calculation more rigid than seems to have been used, and by which I obtain a different result. Lastly, I shall describe the systems of "proofs" of distilled spirits, both of Europe and our own country, and give the results of an experimental comparison of the principal hydrometers used for ascertaining the strength of spirits.

In the subsequent part of this report, I have not ascribed to M. Francœur alone the decimal system developed in it, for it is to Professor R. M. Patterson, director of the United States mint, who urged upon me the expediency of such a system, and who, at the same time, informed me of the admirable method of decimal weighing he has introduced into the United States mint, that I am indebted for the suggestions which caused me to adopt decimal graduation before I knew even of the existence of the memoir of M. Francœur. The idea of decimal division belongs indeed to the age. In the *Journ. de Physique* T. 94, p. 204, there is a paper by M. Delezennes, in which a system of four hundred divisions is discussed; the views it presents may be easily adapted to a centigrade system. Within a few days, I have received from Paris the valuable memoir of M. Francœur on centigrade hydrometers, from which I have made several extracts in this report. But I have endeavored to be just by citing authorities to which I have referred; and these have, when accessible, always been the originals; thus also furnishing, incidentally, references to those who may desire a more extended acquaintance with the subjects of this report.

It is greatly to be regretted, that a report made by Professor R. M. Patterson to the Treasury Department, in 1825, upon the subject of hydrometers, was destroyed when the former treasury building was burnt, and that no copy of it can now be found.

*On the theory of the hydrometer, and a decimal system for its graduation.*

33. By the laws of hydrostatics, it is established that a body immersed in a fluid is buoyed or pressed upwards by a force exactly equal to the weight of the bulk of the fluid which it displaces. Hence, if the body float, the weight of the volume of liquid which would fill the space occupied by the portion immersed is exactly equal to the entire weight of the body itself. From this single fact, with beautiful simplicity, the whole theory of hydrometry readily flows.

For, let the floating body be a hydrometer, having the usual simple construction, represented in Fig. (4) of a graduated stem, a bulb and a counterpoise, or ballast, to preserve it in stable equilibrium when in a vertical position. Let $p$ denote its weight, $y$ the specific gravity or density of the liquid in which it floats, and $x$ the volume of the quantity displaced; then will

$$p = x\,y \quad - \quad - \quad - \quad - \quad - \quad (8).$$

This equation, as $p$ is essentially positive, will be at once recognised as that of the hyperbola referred to its asymptotes. We have therefore a very simple curve for our instrument, which enables us easily to deduce all its properties; and of which the abscissas represent volumes of liquid displaced, and the ordinates the corresponding densities. The consecutive abscissas are therefore the degrees of the graduated stem. If the coördinates are rectangular, then will the hyperbola be equilateral, and $p$ will be the modulus of the corresponding system of logarithms; we shall therefore call $p$ the *modulus* of the hydrometer.

If the constant weight, or modulus, $p$, be determined by a balance, then will equation (8) easily give the value of the specific gravity $y$, corresponding to any particular value of $x$ measured on the stem.

Now, as the differences of the ordinates of the hyperbola corresponding to consecutive abscissas are not equal, it follows that the spaces between the degrees of the stem to read equidifferent specific gravities must be unequal, and that the stem for this purpose cannot be graduated into equal divisions.

34. Whether or not, in the present highly advanced state of philosophical instrument making, it may be easy to graduate a line, so that the degrees shall be laid off accurately at distances corresponding to differences of the ordinates of a hyperbola, practical mechanics only can say. But I should suppose that, as the lengths of these differences may be easily calculated, the graduated micrometer screw of a dividing engine would accomplish the desired object. Geometrical methods are not wanting, and they are so evident that they will readily occur to one acquainted with the elements of conic sections, and need not be given here. But that a hydrometer may be convenient and useful in the arts, it need

not, and perhaps it should not, read specific gravities; for these are usually expressed in decimal fractions; therefore, are recollected with difficulty, and liable to accidental mistakes. The manufacturer has no need of them in his processes; and it is, for instance, far simpler and more easy to remember, that an acid or sirup has the density of 20° Beaumé, than that its specific gravity is 1.166612, that of water being unity. Hence we find that in France, though Brisson brought forward simultaneously a hydrometer reading specific gravities, and succeeded in causing a violent opposition to the instrument of Beaumé, the latter has come into very general use; and not merely in France, but also in other countries of Europe, as well as in the West Indies and our own country. Certainly, therefore, the cause of this must lie in the advantages which in the instrument of Brisson were found wanting. The difficulty of construction, and consequent high price, were perhaps the chief reasons why an instrument based on rigid scientific principles, was superseded by one depending upon arbitrary and uncertain rules; but which was simple and easy in its construction and use, and being of comparatively low cost, was therefore economical. Hydrometers are furnished, of equal accuracy of workmanship and fitness for the same purpose, which vary in cost so much, that one is sold for fifty cents, and another for twenty-five dollars; they are often injured, and must then be replaced. Certainly, therefore, price is a matter of great moment, and simplicity in construction and employment is of essential importance.

35. Nor is it necessary, even in scientific researches, that the densities measured should be always expressed in specific gravities; for simplicity tends to accuracy, and whole degrees of a hydrometer are often better than fractional specific gravities. Yet, as Science belongs not exclusively to any country or nation, she should speak everywhere a common language; nor is any one at liberty to violate its grammar, if he would be understood. Hence a hydrometer scale may be arbitrary, but must be founded upon invariable data, and the degrees of that scale should be translated into corresponding specific gravities when it is desired that they may be intelligible to the world. In article 32 I have shown, that when the *modulus p* is known, and the degree $x$ observed, for any liquid, then the specific gravity $y$ is readily obtained from equation (8) by a very easy calculation. For the reasons above given, further discussion of hydrometers to read specific gravities is here unnecessary, and the simple theory upon which their construction should be based being briefly exposed, the subject may properly be left to men of science and accomplished mechanics. We therefore resume the examination of hydrometers graduated into equal divisions.

36. In equation, (8,) suppose that $y$ becomes equal to unity—a condition which will be fulfilled when the hydrometer is put into distilled water at the temperature of its maximum density—then will $p$ be equal to $x$. *The modulus of a hydrometer is therefore equal to the volume of water at its maximum density which the h y*

*drometer would displace.* There are obvious reasons why the temperature of maximum density is that which should be selected. At that point, a variation of temperature of five or six degrees of Fahrenheit would only cause a difference of 0.0001; nor is there any liability to change from the liquid to a solid state, as is the case at the freezing point, which may be rendered statical by immersion in melting ice.

37. As hydrometers are generally applied to two different classes of fluids—aqueous solutions, which are more valuable as they contain more of the substance dissolved and are more dense; and fluids lighter than water, such as alcohol, which, on the contrary, are stronger as they contain less of water, and become lighter—the degree which corresponds to $p$, the modulus, or which marks the normal density of water, is a zero point for hydrometers, prescribed by the nature of their applications, and therefore having nothing arbitrary or uncertain in its determination. For fluids heavier than water, the degrees would read downwards, and be negative; while, for fluids lighter than water, they would read upwards, and be positive. In either case, the degrees increase in proportion to the quantity of the substance which imparts value to the liquid. The zero point of a hydrometer might be assumed as that of its volume, or at the lower extremity, where $x$ is equal to nothing; and, to avoid fractions, the modulus might be marked 100 on the stem; water would then be 100 instead of unity. To such a scale, the only important objection would probably be, that for fluids denser than water the degrees would read inversely, instead of directly, as their commercial values; and this objection would be found a serious one in its application to the arts.

38. Assuming, therefore, that the modulus of a hydrometer, or its weight, establishes its proper zero point, we may proceed to show how the instrument can be graduated without introducing any thing capricious into its construction. As the equi-different values of $x$ mark the divisions of the scale, and denote in equation (8) volumes displaced, the modulus or normal volume must contain a certain number, whole or fractional, of these divisions, which number is entirely arbitrary, for the variable $x$ is subject only to the condition that its increments shall be equal, though they may be of any magnitude whatever. Accordingly, we find that one of the most general artifices adopted by instrument makers, to render the construction of a particular hydrometer a secret, and a monopoly to their own profit, has consisted in the capricious selection of a value for the increments of $x$, or the divisions of the scale. Add to this another artifice, that of an arbitrary change of the zero point, and we have the explanation of the fact that hydrometers have been multiplied until almost every city of any consequence has produced its hydrometer, known only by the name of its maker, and possessing no peculiar advantages over others, from which it differs in no material respect. I have endeavored to inform myself of all the hydrometers in extensive use, either in Europe or in

our own country, but am still constantly hearing of another, different from the rest only in its particular arbitrary construction. And they may be multiplied indefinitely. If a commercial mystery were not made of the data upon which any one of these instruments is constructed, its indications would be easily intelligible by being convertible into specific gravities; and if broken, it could readily be replaced by any good workman, which cannot be done if the basis of the instrument be kept a secret. Now, all this confusion may and should be done away with, at least in as far as the public service of our country is concerned, by the establishment by law of a system of hydrometry founded upon published and invariable data, and as free from an arbitrary nature as it is practicable for it to be.

It has been shown that some particular volume must be given to the differences of $x$; or, in other words, the modulus must be divided arbitrarily, but we cannot be at a loss to determine what that number ought to be; for the decimal system of notation has become incorporated with all our ideas of number, until they seem almost inseparable from each other. To those who have become accustomed to our beautiful decimal coinage, and have often contrasted it with the complex system of guineas, pounds, shillings, and pence, the decimal division of a scale needs no argument to commend it to their adoption. In trade, articles bought and sold are usually divided, if it all, into halves, or quarters; thus the yard is subdivided rather into halves, quarters, and eighths, than into feet and inches. For convenience, therefore, the fractional parts of the unit of value, the dollar, are halves and quarters; but this does not impair either the utility or beauty of the method of counting by dollars and cents. In strict analogy, therefore, with our simple coinage, the hydrometer may be decimally divided, each degree being equal to the hundredth part of the volume of the modulus, or bulk of distilled water at its maximum density displaced by the floating instrument. And these degrees may be again subdivided decimally into tenths, hundredths, etc., so that any desired degree of sensibility may be given to a hydrometer belonging to this system.

39. It is evident, from equation (8,) that so long as the weight $p$ of a hydrometer remains constant, the value of $x$, corresponding to any given value of $y$, will not vary. Suppose that by a blow the bulb of a metallic hydrometer becomes indented, and its volume consequently diminished, then will it sink deeper to an extent equal in volume to that of the indentation, and this quantity becomes therefore a constant correction of the zero point, to be applied subtractively for fluids lighter than water, or to positive readings, and additively for fluids heavier than water, or to negative readings. But the differences upon the scale will be exact.

40. For any two hydrometers of different weights we have

$$p = x\,y; \qquad p' = x'\,y,$$

when they are plunged into the same fluid, of which $y$ denotes the density; hence,

$$\frac{p}{p'} = \frac{x}{x'};$$

or the degrees are to each other in the constant ratio of their respective moduli. And as this is true for any values of $y$, $x$, and $x'$, which correspond to each other, it is true for all; or, in the decimal system, when

$$x = n\frac{p}{100}, \text{ then } x' = n\frac{p'}{100}.$$

It is therefore evident, that any two hydrometers of the decimal system, however different in their respective weights and sizes, will read the same number of degrees when plunged into the same liquid. And if the sections or diameters of their stems are of the same magnitude, then will the lengths of the degrees, or divisions on the stem, be proportional to the weights of the instruments. Hence it follows that, in Dycas's and Sikes's hydrometers, to which weights are added, the degrees on the graduated stems belong to systems of very different sensibility for each successive weight; or that each weight constitutes in fact a distinct hydrometer of a series, a very complicated arrangement.

41. For the same hydrometer, suppose that $y$ varies geometrically, or that it is immersed in liquids of different specific gravity. When

$$y' = 2y, \text{ then will } x' = \frac{x}{2}.$$

Hence, in hydrometers of the decimal system, 50° below zero will correspond to a specific gravity of 2,000, water being unity. For a specific gravity 1.500,

$$\text{as } y' = \frac{3}{2}y, \text{ and } x' = \frac{2}{3}x;$$

a hydrometer of the decimal system would read $-33\frac{1}{3}°$, while 25° corresponds to a specific gravity of 1.3333. Above zero, if

$$x' = 2x, \qquad y' = \frac{y}{2};$$

then, in the decimal system, + 100° will correspond to a specific gravity of 0.5000. Hence, the hundredth degree of the decimal hydrometer will slightly, but sufficiently, exceed the point requisite to show the specific gravities of sulphuric ether, caoutchoucine, and the lightest known liquids. And all liquids lighter than water,

at present known to chemists, will have their densities comprised between zero and + 100; while those heavier than water will be indicated by the negative degrees from zero to 100° below. The simple law, that the degrees of hydrometers vary inversely as the specific gravities gives rise, as we have seen above, to the fact that specific gravities of $\frac{1}{2}$, $\frac{4}{3}$, $\frac{3}{2}$, 2, etc., correspond to indications of 100° above zero, and 25°, $33\frac{1}{3}$°, 50°, etc., below zero. Nothing, therefore, seems wanting with respect to simplicity in this system.

42. We have hitherto supposed that the weight of the hydrometer is sustained only by the liquid in which it floats; but the air also aids in its support, by the buoyancy it exerts upon the stem. If we denote by $a$ the relative density of air to that of water, and by $v$ the total volume of the hydrometer, then will $v-x'$ be the volume of air occupied by its stem. If we had experimented in vacuo, for the absolute weight $p$, we should have found

$$p = x\,y.$$

But in air we have

$$p = x'\,y + a\,(v - x');$$

$$(x - x') = \frac{a}{y}(v - x') \text{ - - - - - - } (9);$$

which is, therefore, the correction to be added to $x'$, the degree observed in air to reduce it to $x$, the degree for experiments in vacuo. The error committed by disregarding this correction would evidently be least when the density of the liquid or $y$ is greatest. And if $y$ be constant, then will the error vary with $a$; which depends upon the pressure and temperature of the atmosphere, as indicated by the barometer and thermometer; so that

$$a = a' \frac{b}{(1 + k\,t)}$$

will be the value of $a$ in terms of the normal density $a'$; $b$ being the coefficient of pressure, $t$ the degrees of the thermometer observed, and $k$ the coefficient of the atmospheric dilatation. At 60° Fahrenheit and 30 inches of the barometer, the specific gravity of air appears, by the experiments of MM. Biot and Arago, to be 0.001220, water being unity; if we take the cubic inch of water equal to 252.525 grains, then, for a cubic inch of air, we have 0.30808 grains. If the portion of the stem above the surface of the liquid $(v-x')$ be one cubic inch in volume, 0.30808 is therefore the quantity, which, when divided by the density $y$, would give the correction to be applied, provided that our experiments are made at 30 inches of pressure and 60° Fahrenheit. Suppose that the liquid is water, or $y$ equal to unity, and that the hydrometer weighs

500 grains, then will 5 grains correspond to one division of the scale, and 0°.06 will be the error committed by omitting to take into consideration the influence of the atmosphere. Hence, as $y$ varies within narrow limits for all known liquids, except mercury, say from 0.65 to 2.0, we conclude that an allowance for atmospheric pressure need not be made in the ordinary use of hydrometers; and is only called for in nice scientific investigations. Still less is it, therefore, requisite that we should take into account the effects of the barometrical and thermometrical oscillations of the atmosphere on either side of its mean or normal state.

43. We have likewise assumed that observations of the hydrometer are made at the temperature of the maximum density of water, at which the volume of water displaced $x$ becomes equal to $p$, and $y$ is unity. At any other temperature, the volume of water being greater, $y$ will be less than unity, and $x$ will become greater than $p$; or, in other words, the hydrometer will sink. But, as heat generally expands, and loss of heat contracts bodies, whether solid, liquid, or gaseous, the hydrometer itself will undergo a change of volume whenever the temperature of the liquid varies. While, therefore, the dilatation of the liquid tends to sink the hydrometer, its own dilatation causes it to rise; which action is reversed in each for contraction. Hence the influence of temperature tends to work out its own compensation. If the ratio of dilatation were the same, both for the hydrometer and the liquid in which it swims, then would this compensation be perfect; but, as they generally vary very considerably, there will be found an uncompensated equation of dilatation of appreciable magnitude, to be applied to observations made at other temperatures than that of the maximum density of water. And this equation will vary with the coefficient of dilatation of each particular liquid. Hence, it becomes important, and even indispensable, that tables of dilatation should be obtained, by exact researches, for the different liquids to which a hydrometer is applied. From these, as data, tables of correction, having the temperature observed for their argument, should be calculated; or a simple approximate arithmetical rule for corrections may be given, if one can be deduced; or a mechanical scale, with a sliding rule, may be used, to avoid all calculation or use of tables; or, lastly, the thermometer employed may be graduated to read directly, instead of its usual degrees, the corrections to be applied to indications of the hydrometer. The coefficient of dilatation of the particular metal or kind of glass of which a hydrometer is made must also be determined with accuracy by nice experiments. If we consider the dilatation of the hydrometer apart from that of the liquid, then will it cause for each degree of temperature a particular increment of volume, and consequent change, principally of the zero point, which will be constant for different liquids.

To obtain the general law of corrections for temperature, let $k$ be the coefficient of cubic dilatation for the liquid, and $k'$ the corresponding coefficient of the hydrometer; let $t$ also denote the

temperature reckoned from that of maximum density as the origin of temperature; then will

$$y = y'(1 + k\,t) \quad - - - - - - \quad (10).$$

$$p = x'\,y'(1 + k'\,t) \quad - - - - - - \quad (11).$$

From which equation, if we put it under the form

$$p\,\frac{1}{1 + k'\,t} = x'\,y' \quad - - - - - - \quad (12),$$

it appears that the hyperbola will no longer be equilateral, unless $k' = 0$; but that for all values of the coefficient of $p$ less than unity, if we represent this coefficient by sin. $u$, we shall have

$$p \sin.\, u = x'\,y' \quad - - - - - - - \quad (13),$$

which is the equation of a hyperbola, whose asymptotes form with each other an angle equal to $u$, and of which $p$ sin. $u$ is the power. And for any observed indication, or degree $x'$, the corresponding reduced value $y'$ of the density, will be

$$y' = \sin.\, u\,\frac{p}{x'} \quad - - - - - - - \quad (14).$$

As the coefficient of dilatation for solids is always positive, $1 + k'\,t$ will be greater, and sin. $u$ be, therefore, less than unity.

Hence, it follows that, for any particular temperature observed, the indications of the hydrometer and the corresponding specific gravities will be correctly represented by the abscissas and ordinates of a hyperbola referred to oblique asymptotes; and the ratio of unity to the dilatation of the hydrometer will be the sine of the angle formed by the asymptotes with each other; the power of the hyperbola being also the sine of this angle multiplied by the weight of the instrument.

44. Although, in applying to the decimal hydrometer of article 38 the general conclusions derived from equation (8,) where the origin of abscissas is the lower extremity of the instrument, it becomes necessary to introduce the formulæ of transformation of coordinates, which correspond to the zero point given by immersion in distilled water of maximum density, as a new origin of abscissas. Yet, as the values of $y$ remain unaffected by this change, and as

$$x = a - x' = 100 - x',$$

is therefore the only formula of transformation to be introduced into the expressions to refer them to the new axes; it is more simple

to omit the introduction of $a-x'$ into our algebraic expressions, and merely substitute $100-x'$, or the arithmetical complement, in place of $x$, the abscissa, in the numerical value of a formula. This may be performed mentally, as exemplified in article 41 of this paper.

45. Various hydrometers, like that of Dycas, are adapted to liquids of very different specific gravities by the addition of weights; which could not be done otherwise, without making the stems of inconvenient length. It is therefore requisite to give the theory of such instruments; more especially as the mechanical construction of hydrometers belonging to the decimal system should be performed by varying their weights, and as by use of weights we may combine the advantage of a short stem with the simplicity and perfection of decimal graduation.

Suppose, therefore, that we mark the degree $x$, to which the hydrometer sinks in distilled water of maximum density, and that we add internally a known weight, which we shall denote by $w$; then will this cause the hydrometer to sink to a degree marked $x'$, for which the additional quantity of water displaced is equal to $w$ in weight, and $x'-x$ is its volume in degrees. To ascertain the value of $x'-x$, the weight $p$ of the hydrometer must be accurately determined by the balance, and divided into any conventional number of degrees, which number is represented by $n$; then shall we have, by proportion,

$$\frac{n^{\circ}\, w}{p} = (x'-x)^{\circ} \quad - - - - - - - \quad (15).$$

If, for example, we suppose the hydrometer to be of the decimal system, $n=100$, and that it weighs 500 grains, then

$$w = 5\,(x'-x).$$

If $w$ be taken successively equal to 50, 100, 150, 200, etc., grains, $x'-x$ will become 10°, 20°, 30°, 40°, etc.; or, in other words, the additional portion of the stem which the given successive weights cause to be immersed must be graduated into the above corresponding equal divisions. If we subtract instead of adding weights, then will equation (15) still answer, by making $x'-x$ negative; so that

$$w = 5\,(x-x')$$

for hydrometers of the decimal system.

46. Hydrometers of the decimal system may be constructed with weights, but as each weight gives a new modulus and a different length to the divisions of the scale, their stems must be prisms of as many sides and separate graduated scales as there are weights employed. These scales should read continuously, so that the degrees will constitute a single scale.

47. As the degrees of a hydrometer, to be readily observed, should not be less than one-twentieth of an inch in length; the stem of the decimal hydrometer would have the inconvenient length of seven and one-half inches; and the instrument be both extremely fragile and unstable in its vertical position for the lower degrees; there are therefore practical difficulties in the way of constructing and using such an instrument. But in its use it is rarely that it is needed by the same person to perform two different offices, for each employs it only for a particular liquid, as, for instance, the distiller for alcoholic liquors, the brewer for malt solutions, the tanner for those of bark, the manufacturing chemist for acids and salts, the sugar refiner for sirups, &c.; hence it is not only unnecessary, but inexpedient, that the scale of the instrument should extend beyond those degrees which are requisite for the particular purpose to which it is to be applied. And hydrometers may be made with equal facility and less expense of shorter stems, and of any desired degree of sensibility, the divisions of which shall be comprised between the limits of any given degrees of the decimal system, positive or negative, which will best adapt them to their use. Such hydrometers are infinitely preferable to a universal hydrometer; but that they should form parts of one general decimal system is very desirable.

48. The materials of which hydrometers are usually made are glass, silver, copper, brass, and German silver. The great economy of glass, its perfect cleanliness, resistance to corrosion, incapability of fraudulent change of form or weight, and facility of manufacture, are qualities possessed to the same extent by no other known substance. But its fragility prescribes limits to the sensibility of glass hydrometers; and renders metal often preferable. Still, glass instruments only should be used in trade, unless frauds can be otherwise prevented by appropriate legislation. The extent to which abuses are committed by dealers in alcoholic liquors is believed to be enormous; and so it may remain, unless some means be adopted to render them impracticable. The use of glass hydrometers, correctly constructed, and liable to inspection by legally appointed persons, would preclude all fraudulent sales of liquors; and certainly while governments, by standard weights and measures of length and capacity, prevent dishonesty in trade with respect to other articles, they should regard as worthy of their consideration, and of similar protective legislation, a branch of commerce in which the perpetration of crime seems to have become so common as to pass for superior sagacity. Metallic hydrometers may easily be rendered fraudulent; indentations, to which they are ever very liable by accident, operate in favor of the dealer against the purchaser; and in levying duty, they operate for the revenue against the importer. Unless such instruments are inspected, from time to time, no reliance is therefore to be placed upon them. I need not, and I should not, show how hydrometers are designedly rendered fraudulent, and made to operate for or against the purchaser, one for buying, another for selling. I will only

add, that this is very easily done for any metallic hydrometer, but for glass instruments can be readily accomplished only by the makers or by practical chemists. Copper hydrometers, made by the recently discovered electrotype process, may possess advantages over all others of metal. I am told by Mr. Saxton, the distinguished philosophical instrument maker, now employed in the fabrication of the standard weights and measures of the United States, and whose skill is known better perhaps in Europe than in this his native country, that hydrometers could be made by the electrotype method, which would combine facility and superiority of workmanship with greater certainty in use. Their coefficients of dilatation he also thinks would be less variable than those of wrought metal; but upon this subject I beg leave to refer to Mr. Saxton himself, with the remark, however, that I deem it highly important that a series of nice experiments should be made, to determine the coefficient of dilatation and mechanical properties of electrotype copper, with a view to this application. Metallic hydrometers may and should be gilded by electro-gilding with gold or platinum, by which they will be rendered incapable of corrosion by liquids generally, and may perhaps be employed even for acids.

49. As the decimal system of hydrometers, to be of convenient adoption in place of the instruments now in use, and by habit rendered familiar to those who employ them, should be comparable with them by even the most ignorant workmen, it would be advisable, and perhaps necessary, that not only tables of comparison should be constructed, but that the stems should be graduated on their different sides to read both the old and the new degrees. Thus, by daily use, the new and more simple decimal scale would become equally familiar, and the old scales would be abandoned without perceptible inconvenience. Besides, by selecting those instruments which appear to be of greatest accuracy of their particular sorts, they would, by comparison with the decimal system, be referred to perfectly rigid bases of construction as standards, and differences of whole degrees would no longer exist in the instruments employed and offered for sale by the trade. Thus an instrument, having on one side the decimal scale, should be graduated to read degrees Beaumé on the other; and this instrument, regarded simply as a Beaumé's *pèse-acide* or *pèse-esprit*, would possess the advantage over other hydrometers according to Beaumé, of being *always graduated correctly*, an advantage which certainly should recommend it to use.

There are hydrometers in use which read not specific gravities, nor divisions of an arbitrary scale, but per cent. of the substance dissolved which confers value upon the solution; such are, for instance, the beautiful centesimal alcoholometer of M. Gay Lussac, and the *saccharometer* of brewers, which read sometimes the number of pounds of malt extract or fermentible matter in a barrel, and sometimes the per cent. instead. And it is greatly to be desired that the use of such instruments should become more extended; a *pèse-sirop*, for example, might read per cent. of sugar in solution, instead of degrees Beaumé. For such instruments, the decimal

system of hydrometry will furnish by its degrees fixed points of reference, or data of construction, which may be more readily determined than the corresponding specific gravities, to which they are therefore far preferable.

50. In conclusion, it appears from the preceding articles that the greatest disorder exists with reference to the hydrometers now in use; that they are arbitrarily and capriciously, and may be infinitely varied without material advantage, and simply for the commercial purpose of imposing the maker's name upon them; that they are not comparable, because each maker endeavors to keep secret the method of construction he employs, and which alone can render the indications intelligible; that, therefore, if broken, they often cannot readily be replaced; that they are *generally* inaccurate, and often *fraudulently* employed; that they may very easily be rendered fraudulent, if accurate; that, as the division of the scale of the hydrometer is arbitrary, it should be decimal; that this decimal scale should, as some liquid must be employed, be referred to water, distilled that it may be pure, and at its maximum density, because that density is practically stationary; that there should be a single uniform scale of 100 degrees for liquids lighter than water, and 100 degrees for liquids heavier than water; that glass hydrometers cannot readily be rendered fraudulent, except by their makers; that hydrometers of the decimal scale may be constructed of metal, with or without weights; that they are readily graduated by the use of weights; that, by graduating hydrometers to read old established scales on one side of the stem, and degrees of the decimal scale on the other, excellent instruments of the old divisions will replace the inaccurate ones now in use, and even the most ignorant workmen will readily adopt and insensibly acquire the habit of using the simpler decimal hydrometer; that it is, therefore, highly desirable, and worthy of the government of a country like our own, to regulate the use of hydrometers in commerce, and establish a uniform, exact, and invariable system, by authority of law, and that such a system is afforded in the decimal system proposed.

If the government should see fit to adopt a decimal system of hydrometry, it will be requisite that standard instruments be constructed, both in glass and metal; and I shall, therefore, now give practical directions, which it would be necessary to observe in making such hydrometers. But from standard instruments others may be made by tradesmen at less trouble and at less expense, as thermometers are now graduated by comparison with a standard.

*Method of manufacture to be observed by instrument makers, in the construction of standard decimal hydrometers.*

51. We suppose the bulb and stem to have been fashioned, and the instrument ready to receive its counterpoise and graduated scale. Care should be taken that the instrument be constructed symmetrically about its axis, to prevent its leaning when but slightly immersed. If it be intended for liquids lighter than water, add weight *internally* until when immersed in recently distilled

water at the temperature of maximum density, 4° centigrade, or 39½° Fahrenheit, it sinks to the bottom of the stem; the degree it marks will be the zero point of the hydrometer. If, however, the hydrometer be intended for fluids heavier than water, then must its counterpoise cause it to sink to the top of the stem in distilled water of 4° centigrade, as a zero point.

Weigh the hydrometer and its counterpoise accurately by means of a delicate balance, and it will greatly simplify the graduation, if the hydrometer and counterpoise be made to weigh in grains one of the round numbers 100, 200, 300, 400, etc., which may easily be done; then divide this weight by 100, the quotient will be the number of grains which will sink the hydrometer one degree of its scale. If, for instance, the hydrometer weighs 500 grains, then will 5 grains be the weight to be added or subtracted to cause it to sink or rise one degree; 10 grains will give 2°; 15 grains 3°; 50 grains 10°; and so on to 500 grains for 100°, or as far as the length of the stem will admit of the extension of its scale. These weights must be added to hydrometers *internally*, or at *the top of the stem*, if they are to be used for liquids lighter than water, and subtracted from those designed for liquids heavier than water.

If the hydrometer be of glass, weights may easily be added or subtracted by leaving the stem open at the top before it is graduated. A finely graduated slip of paper, of *exactly the same weight* as that intended to receive the degrees of the scale, will serve to mark the depths to which different weights cause the hydrometer to be immersed. After these depths are determined, the weights being restored to that of the modulus, the scale is divided and fixed within the stem in its proper position, and the top is then hermetically sealed.

For metallic instruments, this may be accomplished by counterpoises, of different weights, but *precisely equal volumes;* or a hollow counterpoise may receive internally weights of different amount. It is necessary in all cases that the volume of the bulb and counterpoise should be constantly the same.

By attaching the hydrometer by means of a silk worm's fibre, or a human hair, to the arm of a delicate balance, weights of any desired value may be easily subtracted from it, with greater accuracy and convenience than by any other method.

If the stem of a hydrometer be very fine, the ratio of the capacity of the bulb to the stem will be very great, and the instrument will possess extreme sensibility.

In reading off the degrees, or marking the depths to which the instrument sinks, capillary attraction will cause an elevation of the liquid about the stem. This may be prevented by an extremely thin film of oil.

52. As degrees of the hydrometer are measured by equal volumes of water displaced, it is essential that the stem be of uniform diameter throughout, or that any want of such uniformity be corrected in the graduation. To ascertain whether it be regular, the method suggested by M. Francœur is very accurate and convenient; wrap

a fine thread evenly and closely round the stem a certain number of times, say one hundred, at different places; the measure of the length of the thread required will give the circumference, if divided by the number of its wrappings. If the diameter be found to differ but slightly, then may its variation be rendered practically inappreciable by graduating the stem in portions, as is done for thermometers the tubes of which vary slightly in their bore at different places.

53. To graduate a hydrometer of known weight, which shall be without the degrees between zero and any desired division of the decimal scale, let it be of such weight that it will sink entirely in water, if for a heavier liquid, or so that its bulb may not be wholly submerged, if for lighter liquids; then add or subtract weights for two successive divisions, as described in article 51, and graduate the interval between into the proper corresponding number of degrees or equal fractional parts. Such hydrometers are very generally employed in the arts; for the degrees near to zero, or that of water, are rarely of any use, and only increase the length of the stem inconveniently.

54. To construct hydrometers with weights, consider the instrument and additional weight as a new *modulus*, divide the sum by 100 for the weight corresponding to a degree, and graduate for such degrees a new scale on a different side of the stem. A single scale will not therefore serve for various weights. These weights cannot be immersed if of different size without producing changes of volume by the water they displace, thus affecting the position of the zero point; hence they should be added either internally or at the top of the stem; or the counterpoise may vary in weight, while its volume should be constant.

55. To construct cheap and sufficiently exact hydrometers for the trade, use two different liquids, corresponding to the desired divisions of the decimal scale, prepared by means of a standard hydrometer; and having examined the uniformity of the diameter of the stem graduate the interval between the points to which they sink into the proper number of divisions.

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*Description of the principal hydrometers now or formerly in use.*

56. In this section I shall give an account only of those instruments which have been generally adopted, and therefore are best known in France, England, Germany, and our own country, reserving other and comparatively less familiar hydrometers to be discussed hereafter. The *pèse-acide* and *pèse-esprit* of Beaumé are so commonly found in the workshops of all the above-mentioned countries, that they deserve our first attention.

57. *Beaumé's hydrometers.*—For fluids lighter than water, Beau-

mé invented his *pèse-esprit* (*hydrometer for spirits; Branntweinmesser*, Germ.) and for fluids heavier than water, a single instrument, called, with reference to its particular applications, by the different names of *pèse-acide*, *pèse-sel*, or *pèse-sirop*, (*acid*, *salt*, or *sirop' measure;* and *Säuremesser*, *Salzspindel*, or *Zuckermesser*, Germ.) These instruments are entirely distinct, and form no part of a common system, for they are constructed on different bases. The degrees of one are not equal to those of the other; and the zero point, which is determined for the *pèse-esprit* by a solution containing ten per cent. of common salt, corresponds in the *pèse-acide* to the density of pure water. Hence we shall treat of these instruments separately.

The *pèse-esprit* is constructed by immersion in a solution of common salt, containing, as already stated, ten per cent., to obtain the zero point; then by plunging it into water to determine another point, which Beaumé calls 10°; the interval is graduated equally, and the scale extended by laying off, repeatedly, with a pair of dividers, the same interval upon the stem.

The zero point of the *pèse-acide* is given by the surface of the distilled water in which it floats. Immersion in a solution containing 15 per cent. of common salt fixes the point which is to be marked 15° upon the scale. And degrees beyond 15° are determined by the same process of extension employed for the *pèse-esprit*.

It might at first be supposed that the degrees of these instruments would constitute parts of a common scale; but the densities of two solutions of common salt containing, one 10, and the other 15 per cent., will not be such as to correspond to equal degrees 10° and 15° reckoned from water as a common origin; and, therefore, Beaumé's hydrometers belong to different scales.

It is a great and fundamental defect of these instruments, that their scales are constructed by the multiplication of a unit of length; for workmen generally commit an error in determining the fixed points, on account of the elevation of the liquid upon the stem by capillary attraction; and this error becomes multiplied by each successive repetition. Hence it is easy to perceive the reason why Beaumé's hydrometers, constructed by the same person, and with equal care, often differ whole degrees from each other, when plunged into the same liquid. This fault is the more important, as it affects principally those degrees which are most used. In hydrometers of the decimal system, discussed in the preceding sections of this report, the graduation is performed by the subdivision of a multiple; and, therefore, any error which unavoidably occurs in measuring the fixed points will be diminished in the ratio of the number of divisions of the interval between them, which certainly constitutes a great advantage, and renders accuracy of workmanship almost certain.

Another defect of the process of Beaumé for graduating hydrometers is, that common salt generally contains impurities; and to obtain it, therefore, perfectly pure, is impracticable, without a degree of chemical knowledge which instrument makers rarely pos-

sess. And even if pure salt be obtained, and the solutions be properly mixed, they are liable to evaporation, which will alter their proportions and density.

The uncertainty of the indications of these hydrometers is established by the fact that tables of comparison with the corresponding specific gravities have been experimentally constructed by several distinguished scientific men, which all vary from each other, owing doubtless to the difference of the hydrometers used. Tables IV, and V, give the results obtained by those whose names are above the vertical columns.

Yet the hydrometers of Beaumé, by possessing the advantages of simplicity, cheapness, cleanliness, and adaptation to the liquids for which they are used—solutions of salts, sirups, acids, etc.—and being founded upon known and easy bases of construction, so that they may be made by any workman, have passed into use, notwithstanding the well known imperfections I have mentioned, and to an extent exceeding that of any other hydrometer.

This would be surprising, but for the striking contrast of the advantages mentioned, with the correlative disadvantages of complicated structure, high cost, liability to corrosion, limited application, and patented or secret methods of construction, rendering their manufacture a monopoly, which have justly confined other instruments to particular countries or cities. And here it may be proper to remark, that in our country, as well as in England and France, the government, by peculiar legislation, has rendered the manufacture of hydrometers for the revenue a monopoly, and that the person who long enjoyed this exclusive privilege was the late Mr. Dycas, of Liverpool, England, whose hydrometer is established by law as that to be used in the United States for determining the strength of spirits. Certainly our own mechanics, if any, should enjoy such privileges. The States of Pennsylvania and Maryland, also, have, by statute, adopted "Dycas's Patent Liverpool Hydrometer" as their standard, and so most probably have other States.

58. Now, an instrument which may be accurately, easily, and cheaply made by any workman, is certainly of a nature which should recommend itself in a republican government. And the decimal hydrometer, which combines all the advantages of the instruments of Beaumé, with a freedom from their defects, and the superiority of being founded upon bases which nature everywhere presents, in which there is nothing arbitrary but the system of counting by tens, instead of any other numbers, and the degrees of which are converted into specific gravities by a rule so simple that it may be performed mentally, should certainly be adopted, both by our government and its citizens.

And, as I have already stated, by adopting that scale for Beaumé's hydrometer, which seems best entitled to credit for exactness, and drawing it upon the same slip of paper with the corresponding degrees of the decimal system, instruments may be furnished by tradesmen which will always be accurate, if regarded simply as *pèse-esprits* or *pèse-acides*, of Beaumé. And they will cost only

the additional labor requisite to draw two scales upon the same paper instead of one.

59. To obtain the modulus and a formula for converting degrees of the hydrometers of Beaumé into specific gravities, we must substitute for $y$ the values given by the solutions of salt, and by distilled water, in our fundamental equation (8.) Now, MM. Francœur and Dulong have given, as the result of very careful experiments, $y = 1.0735$ for the solution of 10 per cent., and $y = 1.1094$ for the 15 per cent. solution.

Hence, for the *pèse-esprit*,

$$p = x \text{ - - - - - - - for water;}$$
$$p = 1.0735\, x', \text{ - - for the saline solution;}$$
and $$x - x' = 10°.$$

Hence we have

$$p = \frac{10.735}{0.0735} = 146° \quad \text{- - - - (16.)}$$

Therefore,

$$y = \frac{p}{x}, \text{ becomes } y = \frac{146}{136 + x''} \quad \text{- - - - - - - (17).}$$

In the denominator, we substitute 136, because the zero point is 10 degrees below that of water.

And for the *pèse-acide*,

$$p = x \text{ - - - - - - - in water,}$$
$$p = 1.1094\, x' \text{ - - in the saline solution;}$$
and $$x - x' = 15°.$$

Hence we obtain

$$p = \frac{16.641}{0.1094} = 152° \quad \text{- - - - - - - - (18).}$$

and

$$y = \frac{p}{x} = \frac{152}{152 - x''} \quad \text{- - - - - - - (19).}$$

In the preceding equations, $x''$ denotes the indication of the scale for which $y$ is the corresponding specific gravity. From these formulas, (17) and (19,) tables of comparison with specific gravities

may be calculated, possessing far greater accuracy than any obtained experimentally with the instruments to be found in shops; and such tables would serve to fix the standard scale for Beaumé, which should accompany some of the hydrometers of the decimal system.

60. But as the degrees of the hydrometers are merely the fractional parts into which the modulus is divided, it follows from equations (16) and (18,) that, to convert degrees of the decimal system into degrees Beaumé, every 100 degrees decimal are equivalent to 146 Beaumé, for the *pèse-esprit*. Hence we have the rule: *multiply by* 146, *and divide the product by* 100, *then add* 10 *for the difference of the zero-points.*

And for the *pèse-acide*, to reduce decimal degrees to Beaumé, *multiply by* 152 *and divide by* 100. The zero point is the same.

These operations are reversed when we desire to convert degrees Beaumé into decimal degrees.

61. *Cartier's hydrometer*, (*pèse-esprit.*) This instrument would scarcely deserve notice, were it not for the fact that it was employed by the French government for a long time in levying duties before the centesimal alcoholometer of Gay Lussac was brought forward. Cartier, a goldsmith of Paris, was employed by Beaumé to make metallic hydrometers. Brisson, by his influence, was enabled to prevent the use of Beaumé's hydrometer, though unable to supplant it with his own, reading specific gravities. Cartier divided the scale of Beaumé's instrument, so that every 16 degrees Beaumé should be equal to 15 degrees Cartier. This robbery was not only tolerated, but the government even sanctioned it by the adoption of Cartier's instrument. According to M. Francœur, the 22d degree coincides on both scales; hence we have the equation

$$(22 \pm 16)\,B = (22 \pm 15)\,C;$$

which will enable us readily to convert indications of Beaumé into those of Cartier and *vice versa*.

As the bases of construction of Cartier's hydrometer were kept secret, the instrument, founded upon no established data, varied so that it became different from what it was at first. M. Gay Lussac found for several silver hydrometers submitted to his examination by the *Directeur des Contributions indirectes*, that, as Beaumé had stated, 29 degrees Cartier correspond to 31 of Beaumé. Yet these hydrometers differ from those used by the government in the revenue.

62. *The centesimal alcoholometer of M. Gay Lussac.*—In the little book* of tables and instructions which accompanies this simple and beautiful instrument, it is so briefly and clearly explained

* "Instruction pour l'usage de l'Alcoomètre Centésimale et des tables qui l'accompagnent, Par M. Gay Lussac;" Paris, 1824.

that I will employ the language of M. Gay Lussac, literally translated instead of giving its description at second hand:

"The spirituous liquors known in commerce as *ardent spirits* are mixtures in various proportions of water and perfectly pure alcohol. Their value, therefore, generally depends upon the quantity of alcohol that each contains. To determine this quantity of alcohol, I take pure alcohol by volume, at the temperature of 15° centigrade, (59° Fahrenheit,) as a term of comparison, and I represent its *strength* by 100 *per cent.*, or unity. Hence, *the strength of a liquor is the per cent., by volume, of pure alcohol which it contains at the temperature of* 15° *centigrade.*

"The instrument which I call *the centesimal alcoholometer* is, with respect to its form, an ordinary hydrometer. It is graduated at the temperature of 15° centigrade. Its scale is divided into 100 parts, or degrees, of which each represents a per cent. of alcohol; the degree 0 corresponds to pure water, and the division 100 to alcohol. Plunged into a spirituous liquor at the temperature of 15° centigrade, it indicates at once its strength. For example, if in brandy at the temperature of 15° it sinks to the division of 50, it shows that its strength is 50 per cent.; that is to say, the brandy contains 50 per cent. of its volume of pure alcohol.

"When the liquor is not of the temperature of 15°, a portion is brought to that temperature, either by warming it with the hand, or cooling it by immersion in cold water; but it will be both more convenient and more exact to employ the tables of corection given."

This instrument of M. Gay Lussac is so perfectly simple, and so admirably adapted to the use for which it is designed, that it could not fail to be of the greatest service to commerce, if it should be adopted in place of the complicated, uncertain, and almost unintelligible hydrometers of Sikes, Dycas, and others. The simplicity of his hydrometer renders its cost comparatively trifling. It may be constructed of glass or metal. It is this instrument which, at present, I feel inclined to recommend to the use of our government; before deciding, however, the opinions of persons engaged in the manufacture and sale of spirituous liquors should be consulted and carefully considered, and certain experiments should be performed, which would furnish full and complete information upon every important point connected with its theory, that instructions may be given for its construction, which has been kept secret for commercial purposes, and which instructions should be so simple that any good workman may comprehend and carry them into effect. Their manufacture may then be carried on by our own mechanics.

At present, the alcoholometer of Gay Lussac may be purchased in our large cities of persons who import it from France; and, on account of its superiority and low price, it deserves the attention of distillers and dealers in spirituous liquors. In the Dictionary of Arts and Manufactures, by Dr. Ure, (article Alcohol,) and the valuable Encyclopedia of Chemistry of Messrs. Booth and Boyé, (article Alcoholometry,) will also be found the tables of correction for temperature given by M. Gay Lussac.

The government of Sweden has, at the recommendation, I be-

lieve, of the celebrated Berzelius, adopted the centesimal alcoholometer. In Prussia and Austria, similar instruments by Tralles and Meissner have been established by the authority of law. Whether other countries employ it, I have not at present sources of information at command.

As the theory of this instrument will probably be discussed fully in a subsequent report, and after the above-mentioned experiments shall have been performed, I pass to the description and discussion of English hydrometers.

*British hydrometers.*

63. Of perhaps fifty different instruments which have been used in England, I shall describe but few, and discuss only those of Dycas and Sikes. The first, because it is adopted by act of Congress approved August 10, 1790, as the hydrometer to be used in levying duties in the United States; and the second, because it is employed in the revenue of Great Britain; both of which hydrometers are, however, exceedingly complicated, and therefore very uncertain and imperfect.

64. *Clarke's hydrometer.*—This is the oldest hydrometer established by law for the British government; it is particularly described by its inventor in the Philosophical Transactions of the Royal Society for the year 1730; and at that early day, when exact knowledge of the dilatation of alcohol and of metals had not been obtained by experiment, the correction for temperature supplied by this instrument, though very imperfect, constituted a decided superiority over other hydrometers in use. The instrument before me was intrusted to the Office of Weights and Measures by the Treasury Department, No. 11,679, made of copper by the hydrometer makers to his Majesty's honorable Board of Excise. The bulb is about one inch in diameter; the stem very slender, and flat, having the proof point marked by an inlaid silver bead, above and below which it is graduated from one to ten; it is accompanied by thirty-two weights, to adapt it to liquors of different density; and eleven weights for temperature, marked successively from 32° to 80° Fahrenheit, "*very cold*, *colder*, *cold*, *coldish*, *temperate*, *warmish*, *warm*, *warmer*, *hot*, *hotter*, *very hot*," which adjectives are defined by corresponding degrees upon the scale of the accompanying thermometer.

65. The importance of a correction for temperature will be felt, if it be borne in mind that the change of bulk of spirit containing 50 per cent of alcohol is such that there is a difference of two gallons and a half in every hundred, according to the experiments of Gilpin, produced by a variation of temperature from 32° to 80° Fahrenheit, which for our purposes may be considered as the temperatures of summer and winter for the mean climate of the United States. The rise and fall of the liquid in the tube of a thermometer is a familiar instance of this change of volume by variation of temperature.

66. The system of describing the strength of liquors corresponding to Clarke's hydrometer, and given by numbers engraved upon the weights, was as follows: For spirits *over proof*, 1 *to* 2, 1 *to* 3, 1 *to* 4, &c., implied one gallon of water must be mixed with two, three, four, etc., respectively, of liquor, to reduce it to proof. And for spirits *under proof*, 1 *in* 2, 1 *in* 3, 1 *in* 4, etc., denoted that one gallon of water taken from 2, 3, 4, etc., would reduce the liquors to *proof* spirit.

By act of Parliament, 1762, the specific gravity of proof spirit was established as 0.916 at 60° Fahr. But the proof spirit of Clarke's hydrometer was in error 0.004, as shown by the following table of Lowitz for the indications of that instrument:

| Hydrometer. | Sp. gravity. | Hydrometer. | Sp. gravity. |
|---|---|---|---|
| 1 in 2 | 0.9644 | 1 to 20 | 0.9162 |
| 1 in 5 | 0.9424 | 1 to 15 | 0.9135 |
| 1 in 10 | 0.9320 | 1 to 10 | 0.9107 |
| 1 in 15 | 0.9280 | 1 to 5 | 0.8961 |
| 1 in 20 | 0.9265 | 1 to 2 | 0.8590 |
| Proof | 0.9200 | Alcohol | 0.8338 |

By subsequent act of Parliament, the proofs of Clarke's hydrometer were fixed relatively to those of Sikes's hydrometer, as follows:

| *Clarke's.* | *Sikes's.* |
|---|---|
| One to nine over proof | = nine per cent. above proof. |
| One to ten over proof | = seven per cent. above proof. |
| One in eight under proof | = thirteen per cent. under proof. |
| One in six under proof | = seventeen per cent. under proof. |
| One in five under proof | = twenty-two per cent. under proof. |

The duties were charged only upon proof spirit, and a calculation had to be made, to ascertain the quantity thereof contained in any liquor.

67. Owing to the imperfections of Clarke's hydrometer, it was abandoned, and Jones's, Quin's, Dycas's, Speers's, Atkins's, and Sikes's hydrometers came successively into use. The first three of these were substantially the same as Clarke's and may be considered simply as improvements rendered necessary by its faults, and performed but imperfectly, for want of thorough knowledge.

I shall describe Dycas's hydrometer among those of the United States; but it were useless to give a detailed account of the instruments which went into disuse when the government of Great Britain adopted the hydrometer of Sikes, and which seem to have been contrived to suit the system of *proofs* established in trade by the use of Clarke's hydrometer, and therefore to have produced no permanent and material effect upon the practice of that government. Besides, as these hydrometers possess no superiority, they are therefore objects of curiosity rather than of scientific consideration.

68. In consequence of the confusion and want of certain knowledge with which the subject of hydrometers seemed to be invested, the British government applied to the Royal Society; at the recommendation of which, a laborious and accurate series of researches were undertaken and performed by Sir Charles Blagden and Mr. Gilpin; the results of which were published in full in the transactions of that society for the years 1790, 1792, and 1794. The accuracy and fidelity with which this task was performed, and the refinement of the methods employed, entitles these researches to all the admiration and praise that has been so liberally bestowed upon them by those who have taken the pains to examine them; and it would perhaps be but justice to say, that they would do honor to the more refined science of our day, when the art of philosophical instrument making has been carried to a degree of perfection which is indeed wonderful, and the sister art of experimenting has become a calling which can be learned only by serving an apprenticeship under a skilful and experienced master.

It is a fact, strange and unaccountable as it may appear, that though Messrs. Gilpin and Blagden performed their task in a manner which could not have been surpassed, and obtained all the information requisite to furnish a perfect instrument and system of inspection for spirits, the British government neglected to apply the knowledge obtained to its legitimate object. And, twenty years afterwards, the complicated, imperfect, and uncertain hydrometer of Sikes was established by law as that to be used in the revenue of the United Kingdom; though its basis and method of construction are to a great extent arbitrary, and seem to have been kept secret by its inventor, perhaps for purposes of personal emolument.

In Prussia, however, the labors of Messrs. Blagden and Gilpin produced better fruit; for they were there employed by Tralles, who founded upon them his *centesimal alcoholometer*, and method of levying duties by per cent. of alcohol. These were adopted by the Prussian government; and they differ in no material respect from the similar system established at the suggestion of M. Gay Lussac by the government of France.

Nor was this action of the British government owing to any want of proper instruction on the part of Messrs. Blagden and Gilpin; for in his report Mr. Blagden remarks,* after speaking of the requisite points of attention to render a hydrometer adapted to the purpose: "I am still of the opinion that the best way of laying the duty would be directly on the quantity of alcohol contained in any composition." He then proceeds to show how tables may be constructed for this object for each temperature and indication, which will give a "decimal multiplier;" which use of a decimal multiplier, the ratio of the alcohol to the whole mixture, is no other than the method of per cent. by volume of Tralles and Gay Lussac, so highly esteemed, in the commerce of their respective countries, for its accuracy, convenience, and simplicity.

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* See Philosophical Transactions, 1792, p. 436.

69. *Sikes's hydrometer.*—I describe the instrument furnished by the Treasury Department to the office of Weights and Measures, and made by R. B. Bate, of London, "hydrometer maker for the revenue of the United Kingdom," established 22d July, 1816, by act of Parliament, (58 George III., cap. 28,) and accompanied by a thermometer and a book of tables containing 62 pages quarto and entitled "Sikes's table of the concentrated strength of spirits, with directions for the use of his hydrometer." This hydrometer is of brass, and consists of a spherical bulb about one inch and a half in diameter, to which is attached below a slender conical rod about one inch and a quarter in length, which carries at its end a counterpoise of a half inch nearly in diameter, to give it the requisite stability. Above the bulb is attached the stem, flattened and graduated *with a single scale* into ten equal divisions, numbered from 1 to 10, which are again subdivided into five fractional parts of two tenths each. The length of this stem is about three and one-half inches, and the entire length of the instrument is six and one-half inches nearly.

The instrument is accompanied by nine differents weights, of *unequal volume;* the form of which is that of a divided ring, so that they may be placed upon the conical rod, and then slid down to the counterpoise, where the increased diameter of the cone prevents their falling off in the liquid. By means of these weights, numbered 10, 20, 30, etc., to 90, the hydrometer scale is extended to 100 divisions, of which the units are read off upon the graduated stem, and the tens are given by the weights. If we consider the fractional parts of two tenths each, then the scale comprises 500 divisions.

On the side or edge of the stem there is a mark to which the weight 60 depresses the instrument in *proof spirit* at 51° Fahrenheit. By the act of Parliament establishing the use of this hydrometer, *proof spirit* is defined to be *that which at* 51° *Fahrenheit weighs exactly twelve-thirteenths of an equal bulk of distilled water.* The hydrometer is therefore accompanied also by a small square weight, having a hole in one side by which it may be fixed upon the top of the graduated stem, and which weighs one-twelfth of the entire weight of the instrument and weight numbered 60. When added, this square weight sinks the hydrometer in distilled water to the proof mark, and shows that the instrument is constructed in accordance with the definition of the act of Parliament.

The thermometer is of Fahrenheit's scale; and the book of tables shows for every indication and temperature, from 30° to 80° Fahrenheit, the corresponding *over proof* or *under proof.*

This hydrometer is sometimes accompanied by a "sliding rule," somewhat like that which is used for Dycas's hydrometer, and which gives the strength, mechanically, by causing the star to coincide with the observed temperature, and then reading off the proof opposite the indication or division given by the hydrometer.

70. There are two serious objections to the use of a hydrometer of this description; the first arising from the fact that weights of

unequal volume are added below the surface of liquids of different density, which renders the theory of the instrument so complicated as to be incomprehensible to workmen generally, and requires, for its construction to attain certainty, an amount of mathematical calculation which should not be demanded, as there is no necessity for it. And should the instrument maker follow the process of servilely copying one instrument from another, then it seems to me there can be no ground for confidence in his work. The second objection is, that a single divided scale upon the stem causes the divisions to correspond to a different arbitrary system of graduation for each successive weight and modulus; thus destroying all unity and simplicity.

The force of these objections will be better felt by an inspection of the mathematical theory of Sikes's hydrometer, which I give as developed by M. Francœur in his valuable memoir, already referred to, (art. 32,) and which is not, as far as I am aware, to be found in any English publication.

71. The instrument should be of such volume and weight, that, when floated in absolute alcohol, a small portion of the stem will be above the surface of the liquid; and when plunged into water, an additional immersed weight should cause the surface to be a little above the bulb. That these conditions, requisite to fix the zero point and division 10 of its scale, may be fulfilled, it is necessary to perform the following preliminary experiments.

Having weighed the instrument, add weights *internally*, or *at the top of the stem*, until it sinks in distilled water to the division 10, just above the bulb. The entire weight thus given, and which we denote by $v'$, will, as the density of water is known, determine the volume of water displaced. Then add weights, in a similar manner, until the hydrometer sinks to a point near the top of its stem, which should be taken as the zero point; denote this second weight by $v$; we shall thus obtain $k=v-v'$; and these weights $v-v'$ and $k$ will give the volumes corresponding respectively to the zero point, to division 10, and to the graduated portion of the stem.

Now since, by equation (8), $p=xy$, if $\Pi$ be the density of absolute alcohol, it becomes necessary to the end, that the hydrometer shall sink in alcohol to the zero point, that it should fulfil the condition

$$p = \Pi v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20).$$

In which equation, $p$ is the weight of the instrument without its additional weights.

That it may sink in distilled water to division 10, we must add a weight upon the conical rod *beneath the surface*, equal to $m$ grains; if $d$ represents the specific gravity of the metal, then will $m$, divided by $d$, be the volume beneath the surface. So that division 10 will correspond to the volume and equation,

$$v' + \frac{m}{d} = p + m;$$

the density of water being unity. Hence we obtain

$$m = (v' - p)\,\frac{d}{d-1} \quad - - - - - \quad (21).$$

And the two fundamental conditions, that it should sink in absolute alcohol to zero, and with an additional immersed weight $m$ to division 10 in distilled water, by equations (20) and (21), are fulfilled.

If the hydrometer sinks to its zero point in a liquid of which the density is denoted by $\delta$; and, when loaded with one of its weights $\varphi$, then will

$$p + \varphi = \delta\left(v + \frac{\varphi}{d}\right) \quad - - - - - - \quad (22).$$

And that it may sink in the same liquid to division 10, we substitute a different weight $\varphi'$ which is lighter; and

$$p + \varphi' = \delta\left(v' + \frac{\varphi'}{d}\right);$$

by elimination,

$$\frac{p + \varphi'}{p + \varphi} = \frac{v' + \frac{\varphi'}{d}}{v + \frac{\varphi}{d}};$$

hence

$$(\varphi - \varphi')\left(v - \frac{p}{d}\right) = (p + \varphi).\ (v - v') = k\,(p + \varphi);$$

and putting

$$k = n\left(v - \frac{p}{d}\right) \quad - - - - - - \quad (23)$$

we get

$$\varphi' = \varphi\,(1 - n) - n\,p \quad - - - - \quad (24).$$

When, therefore, the hydrometer is loaded with the weight $\varphi$, and sinks to zero, it will sink only to division 10°, if the weight $\varphi'$ be substituted in its place.

72. Suppose that we make $\varphi = m$ the weight which causes the hydrometer to sink to division 10; then will the indication be read off as 100°, since $m = 90$.

Then, in a less dense liquid, in which the weight 90 causes the hydrometer to sink to zero, the indication will be 90; if we re-

place this weight $\varphi$ by another $\varphi'$, which shall sink it only to division 10, we shall have $\varphi' = 80$; and if we substitute $\varphi'$ for $\varphi$, we may, in a similar manner, obtain $\varphi'' = 70$; and so on. Thus we shall obtain, successively, each of the weights, from 90 downwards to 10, of the series which constitutes the scale of the hydrometer.

As the weights are of copper, the specific gravity of which is 8.396, we shall have

$$m = 1.1352\,(v' - p) \quad - - - - - \quad (25).$$

$$n = \frac{k}{v - 0119\,p} \quad - - - - - - - \quad (26.)$$

From equation (22) we obtain

$$\delta = \frac{p + \varphi}{v + 0.119\,\varphi};$$

which gives the specific gravity of the liquid in which the weight $\varphi$ sinks the hydrometer to zero.

M. Francœur found a hydrometer of Sikes to weigh $p = 29.65$ grammes, and that the volumes immersed corresponding to 0° and 10° were respectively $v = 36.25$ and $v' = 35.52$ cubic centimetres; hence $k = v - v' = 0.73$ cubic centim. The weight requisite to sink the instrument to 10° in water was therefore $m = 6.663$ grammes; and $n = 0.0223$ and $1 - n = 0.9777$. From which data M. Francœur constructed the following table:

| Degrees. | Additional weight, in grammes. $m$. | Specific gravity of spirit. $\delta$. | Degrees. | Additional weight, in grammes. $m$. | Specific gravity of spirit. $\delta$. |
|---|---|---|---|---|---|
| 90 | 6.663 | 6.9804 | 40 | 2.793 | 0.8869 |
| 80 | 5.856 | 0.9608 | 30 | 2.073 | 0.8692 |
| 70 | 5.064 | 0.9420 | 20 | 1.367 | 0.8518 |
| 60 | 4.290 | 0.9233 | 10 | 0.675 | 0.8347 |
| 50 | 3.533 | 0.9049 | 0 | 0.000 | 0.8179 |

73. I would here remark, that, according to M. Francœur, the hydrometer of Sikes is no other than that which had been long in use in Montpelier, and which was invented by Dr. Bories, who based it upon accurate experiments of his own. Mr. Sikes professes to have calculated his tables from the data furnished by Messrs. Gilpin and Blagden. The hydrometer of Sikes too closely resembles that of Mr. Atkins and others which preceded it, to render it probable that he merely copied after Dr. Bories; such, how-

ever may possibly have been the fact. For a description of Bories's hydrometer, M. Francœur refers to the *Bulletin de la Société d'Encouragement*, 5e. *année* 1806, p. 185. In a subsequent section of this report will be found experiments of comparison and verification for Sikes's hydrometer.

74. According to Dr. Ure* the Lords of the Treasury recently requested the Royal Society to examine the construction of Sikes's hydrometer, and its fitness for its purpose. Of the action of the Society upon this application I have been unable to find any account, either in its Transactions or Bulletins of proceedings. Dr. Ure states, however, that a committee was appointed, who recommended a different system, and the use of a hydrometer reading specific gravities. Mr. Bate, the hydrometer maker for the revenue, brought forward a new instrument, a peculiarity of which is, that the additional weights differ successively in volume by a quantity equal to the portion of the stem which forms the graduated scale; this would add greatly to the trouble and difficulty of manufacture, and consequently to the cost. Mr. Lubbock seems to have been intrusted with these investigations, and the report of the committee, to which Dr. Ure furnishes no reference, is, I have reason to believe, contained in the Parliamentary papers. The well established and high reputation of Mr. Lubbock entitles any thing coming from his pen to careful consideration; therefore, and because no change has yet been made, as far as I have been able to learn, in the system of Great Britain with relation to these matters, I shall defer all further remarks until I shall have succeeded in obtaining the report made by the committee of the Royal Society upon this subject.

Omitting all notice of other and comparatively unimportant English hydrometers, which are not few in number, I pass to the discussion of those employed in other countries.

### *Hydrometers of Prussia.*

75. *Centesimal alcoholometer of Tralles.*—This instrument may be regarded as the same as that of M. Gay Lussac, from which it differs very slightly; the specific gravity of water is taken by Tralles as unity at the temperature of its maximum density, so that it becomes 0.9991 at 60° Fahrenheit. Gay Lussac assumes it to be unity at the temperature of 15° centigrade. Again, M. Gay Lussac defines *absolute alcohol* as that which possesses the specific gravity of 0.7947 at the normal temperature, 15° centig.; while Tralles assigns to it the specific gravity of 0.7939 at 60° Fahrenheit. These temperatures differ by one degree Fahrenheit, which would cause a variation in specific gravity of 0.0005 only; to be added to that given by Tralles, which becomes 0.7944. The difference 0.0003 is sufficiently accounted for by the different units selected, and by

*See Ure's Dictionary of Arts and Manufactures, article Alcohol, page 20, London edition.

the well-known fact, that the zero points of thermometers become somewhat displaced after manufacture and by use; hence, this discrepancy falls within the limits of instrumental errors.

The researches of Tralles were published in the year 1811;* the results of those of M. Gay Lussac in 1824. Tralles bases his tables upon the weighings of Messrs. Gilpin and Blagden; M. Gay Lussac upon experiments of his own which he has not made public. The tables given by M. Gay Lussac in the little book to which I have referred are far more complete than those of Tralles, or any others extant. These tables are also contained in full, as well as those of Tralles, in the Encyclopedia of Messrs. Booth and Boyé, (art. Alcoholometry,) and they well deserve the praise bestowed upon them by Dr. Ure in the remarks:†

"I consider the preceding table, which I have extracted from the longer tables of M. Gay Lussac, an important addition to the resources of British dealers and manufacturing chemists. With his little instrument, the real value of any spirituous liquor may be determined to sufficient nicety for most purposes, and by a far easier manner than by any instruments now used in this country."

Tralles has given full instructions for the construction of his centesimal alcoholometer; these are not published for the instrument of Gay Lussac, the manufacture of which seems to be secured by patent to MM. Gay Lussac and Colardeau. M. Collardeau, a pupil of the Polytechnic school, was the assistant of M. Gay Lussac in his labors.

76. *Richter's Alkoholometer.*—The instrument which has borne this name is simply a hydrometer of the ordinary construction, graduated so that its degrees shall indicate the per cent. of alcohol, *by weight*, contained in a spirituous liquor. It is inferior in convenience and utility to that of Tralles, which gives per cent. *by volume*, because liquors are bought and sold by measure instead of weight.

This hydrometer has been constructed of several kinds, based upon different data;‡ the first was founded upon Richter's earlier researches, and showed the per cent. of alcohol of the specific gravity 0.821; the second upon Lowitz's tables, making the specific gravity of absolute alcohol 0.791 at 16° Reaumur; and the third upon Richters's later determinations, giving 0.792 for the specific gravity of absolute alcohol.

Richter also founded his hydrometer upon but five observations interpolated arbitrarily, and made only at the single temperature of 16° Reaumur. As he retained this basis even in later constructions, it is strange that his instrument gave determinations so approximate to truth.

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*See Untersuchungen über die specif. Gewichte der Misehungen aus Alkohol und Wasser, und Tafeln für den Gebrauch und die Verfertigung der Alkoholometer, vom Prof. Tralles, Secret. d. math. Klasse d. Akad. d. Wissensch. zu Berlin. In Annalen der Physik, von L. W. Gilbert, Jahrgang 1811, Stück 8.

†See Dr. Ure's Dictionary of Arts and Manufactures, London edition, p. 28, art. Alcohol.

‡ See Meissner's Aräometrie, Wien, 1836, p. 192.

77. The hydrometer now constructed and known in Prussia by the name of *Richter's alkoholometer*, is a very different instrument, based upon the labors of Tralles and observations of Messrs. Gilpin and Blagden,* which possess all requisite exactness.

78. *Alkoholometer of Lowitz.*—According to Meissner, although Lowitz never gave his attention to the subject of constructing a hydrometer, yet many instruments were founded upon his tables, published in *Crell's Annalen*. Richter set the example, and many artists followed it, in Russia, Poland, and Germany; so that hydrometers, founded upon Lowitz's determinations, became common, and most of them bore the name "*Alkoholometer nach Lowitz.*"

79. *Universal areometer of Richter*—(*allgemeines Aräometer.*)—This instrument was intended to read specific gravities; but Richter fell into the error of supposing that a scale graduated into equal parts would give equal variations of specific gravity. We have seen that, for this purpose, the divisions should vary with the ordinates of a hyperbola referred to its asymptotes. Poggendorf states that the inaccuracy and inconvenience of this instrument have caused it to pass entirely out of use.

80. *Schmidt's Aräometer.*—This is a hydrometer so constructed as to read specific gravities with accuracy; the geometrical construction for which is described in (Gren's N. Journal d. Physik, 1796,) and also by Poggendorff, in his excellent article on *Aräometrie*, in the *Handwörterbuch der Chemie.*† The above mentioned hydrometers are made by J. J. Greiner, of Berlin, with a degree of skill which probably surpasses, for such instruments, that of any other artist in Europe.

*In Austria.*

81. *Meissner's Alkoholometer.*—An instrument consisting of a combination of the scale of per cent. by volume with that for per cent. by weight, and founded upon independent experiments and determinations by its author, has long been in use as the hydrometer of the government of Austria. This instrument, bearing two graduated scales, may therefore be considered as a union of Richter's scale with that of Tralles. As the data differ upon which the centesimal alcoholometers of Tralles, Gay Lussac, Meissner, and Richter, are founded, the indications will not correspond exactly. (Table VI of the appendix will serve to show their differences.)

82. *Universal Areometer of Meissner*—(*allgemeines Aräometer.*)—This hydrometer reads specific gravities from 0.700 to 2.000.

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* Handwörterbuch der Chemie, von Liebig, Poggendorff, und Wöhler. (pp. 264 und 474.) Braunschweig, 1842.

† Aräometrie, p. 130, § 325.

The divisions of its scale are unequal in volume, and the instrument is therefore liable to all the objections already urged with reference to hydrometers graduated to indicate specific gravities. To what extent it may be in use, I have no means of ascertaining; it is described in *Meissner's Aräometrie*, already referred to; a work regarded in Germany as high authority upon the subject of which it treats, and a copy of which my friend, Professor J. C. Booth, has kindly placed at my service.

83. Professor Meissner has also described, in his valuable treatise, several *special hydrometers*, (*besondere Aräometer*,) so constructed as to show the quantity of the substance which imparts value to the liquid. One of these (*Schwefelsäuremesser*) is intended for sulphuric acid; others, analogous to it, are adapted to nitric acid and hydrochloric acid; another is applicable to ammonia. And he has constructed tables which give the specific gravities corresponding to every five per cent. from zero to one hundred.

*The Holland hydrometer.*

84. The medical faculty of Amsterdam adopted a modification of Beaumé's hydrometers, which has since been known as the Holland hydrometer, (*das holländische Aräometer*,) or hydrometer of the *pharmacopea batava*, 1805. Beaumé, as we have seen, employed solutions of common salt for his hydrometer for spirits, (*pèse-esprit*,) and 15 per cent. for his hydrometer for liquids heavier than water, (*pèse-acide*.) Water, which corresponds to 10 of the *pèse-esprit*, marks the zero point of the *pèse-acide*. The *Holland hydrometer* has the specific gravity of water 1.000 at 10° Reaumur, (54½° Fahrenheit,) for the density corresponding to its zero point. The 10th degree of its scale is determined by a solution containing 10 per cent. of its weight of common salt; and the degrees are all equal, both above and below zero.

*In Switzerland.*

85. *The hydrometer of Beck*, an instrument maker of Bern, has become very generally known. It is sometimes called *Bentely's hydrometer;* and is merely a modification of *Beaumé's*, proposed by Bentely, having the density of water at 10° Reaumur for that of its zero point, while its 30th degree is determined by a liquid of the specific gravity of 0 850. This instrument is therefore free from the errors which are produced in the graduation of Beaumé's hydrometer by the use of the method of repetition of units to extend the scale, instead of that of subdivision of a multiple. The divisions of its scale are also equal, whether positive or negative.

*Hydrometers of America.*

86. *Hydrometer made by Tucker & Dwelle, of Boston.*—This instrument is accompanied by a thermometer and sliding rule. That

which has been submitted by the Treasury Department is marked No. 81. It is of silver; this is deemed by the makers a great advantage, for the assigned reason, that it is less liable to corrode than copper. This hydrometer is accompanied by ten additional weights, which, in form and in the manner of their application upon a conical rod connecting the bulb and counterpoise, are identical with the construction of Sikes's hydrometer. Although the scale of this hydrometer reads from zero to 100 instead of from 100 to zero, as in Sikes's, and although the sliding rule professes to be adapted to the American system of proofs, it still seems to me that this is no other than Sikes's hydrometer under a new name, and in a dress of the American fashion.

87. *Southworth's hydrometer.*—This instrument is established by law of the State of New York as the standard for that State. Apart from the question of accuracy of construction, it possesses merit; for the divisions of the scale indicate per cent. above or below proof directly, and without recourse to any sliding rule or set of tables. The proof mark is thus the zero point of graduation. This arrangement appears to be much simpler than any other which has been brought forward to determine the strength relating to proof spirit; and it deserves consideration, if the present system of proofs be continued. But in simplicity no instrument compares with the centesimal alcoholometer of Tralles and Gay Lussac. The workmanship of the instrument belonging to the Treasury Department appears to be very rough, and its graduation inaccurately performed. I regret that it was not in my possession when I performed the experiments of comparison given in a subsequent part of this report. But I doubt very much its accuracy; and the rule given by Mr. Southworth of correction for temperature appears to be no other than that of M. Francœur for the alcoholometer of M. Gay Lussac, with this great oversight, if it be so, that degrees Fahrenheit are substituted in place of degrees centigrade, without reduction. But I dismiss the expression of surmise, and defer all further remarks upon this instrument until experiments with it shall have put me in possession of all necessary facts.

88. *Dycas's hydrometer.*—The theory of this hydrometer has been already partially set forth in my general discussion of the theory of hydrometers; and particularly in articles 40, 45, 46, and 54. The instrument before me, made by Fisher, of Philadelphia, No. 342, belongs to the Treasury Department, and is similar to those now in use in the revenue of the United States. It is copied strictly after one made by the late Mr. Dycas of Liverpool, which is used by Mr. Fisher as a standard.

The bulb is an oval gilded copper or brass ball about one inch and a half in diameter; to this ball is fixed a slender stem, graduated in equal divisions of a *single* scale, and terminating in a point which fits the holes at the centres of the different weights; by that means they are attached when the hydrometer is in use. Below the bulb, a counterpoise is fastened to the end of a rod in the ordinary

manner. The whole instrument is about seven inches long, and it is accompanied by thirty-six circular perforated weights, marked 0 to 350, which is the lightest. At the top of the stem is stamped the number 360, which corresponds to the instrument without weights, and enables the scale to be extended to 370. In the same box with the hydrometer are also a Fahrenheit thermometer, and an ivory sliding rule.

The instrument has therefore a series of 370 indications; but as the moduli vary with the weights, the degrees will not belong to a single system, and the scale may be in fact regarded as a combination of thirty-seven different scales. The hydrometer indications are marked upon the slide, or middle portion of the sliding rule, from 0 to 370, water being zero; and the corresponding strengths above and below Dycas's proof spirit are marked upon the margin, or fixed part of the rule, opposite to the indications. To adapt this instrument to different temperatures, as shown by the accompanying thermometer, the left hand part of the slides has upon its side a graduated scale from 30° to 80° Fahrenheit. And when the index upon the margin is placed opposite the temperature observed, then will the indication observed correspond to the particular strength of the liquor examined.

89. To obtain a formula by which to calculate the values of the successive weights of Dycas's hydrometer, we must pursue a train of reasoning somewhat analogous to that of M. Francœur for Sikes's hydrometer, developed in article 71. Having first weighed the instrument itself we ascertain the respective volumes displaced when it sinks in water at 40° Fahrenheit to its zero point and to division 10 of the stem, by adding known weights and calculating the volumes therefrom. Call these volumes $v$ and $v'$; then will $v' - v$ be the volume of the graduated portion of the stem, and we will represent it by $k$.

Denote the weight of the hydrometer alone by $p$, and suppose that when loaded with the additional weight $w$ it sinks to zero, then if we add a second weight which shall be equal to $k\,d$, the hydrometer will sink to division 10 of the scale, $d$ being the density of the liquid. Hence,

$$w' = w + k\,d;$$

For the density $d$ we have

$$d = \frac{p + w}{v} \quad - - - - - - - \quad (28);$$

and, therefore,

$$w' = w\,(1 + n) + p\,n \quad - - - - \quad (29);$$

making $k$, divided by $v$, equal to $n$.

The difference of the specific gravities of the liquids in which

the same weight $w$ causes the hydrometer to sink to zero in the one and to division 10 in the other, will be

$$d - d' = (p + w)\left(\frac{v' - v}{vv'}\right) = (p + w)\frac{n}{v'} \quad - \quad (30);$$

we shall have

$$d - d'' = (w - w'')\frac{1}{v} \quad - \quad - \quad - \quad - \quad (31),$$

for the relation between any two specific gravities and the weights which cause the corresponding indications to be each equal to zero.

I have now described nearly all the important hydrometers in general use. There are others, such as Allen's, Bate's, Richardson's, Dycas's, and Southworth's saccharometers for brewers, and Twaddle's hydrometer for fluids heavier than water, which may hereafter be discussed. But, for the present, omitting to do any thing more than mention their names, and reserving all further remarks upon Dycas's hydrometer, as well as a more particular account of the ivory sliding rule which accompanies it, for the sequel, I pass to the next division of my report.

*On the temperature of the maximum density of water.*

90. The practical importance of determining the temperature at which water attains its maximum density, and the law of its dilatation for variations of heat near that temperature, is apparent, from the reasons already given why it should be employed to fix the modulus or zero point of hydrometers. But as this temperature is also adopted by governments, and our own among the number, for the establishment of accurate weights and measures, it becomes of the highest interest and necessity, apart from mere scientific considerations, to ascertain it with all possible refinement, both of experiment and calculation.

So many distinguished scientific men have devoted their attention to this subject, and tasked their ingenuity to discover methods of refined observation, that it seems scarcely practicable in the present state of experimental science, and of our knowledge of the laws of heat, to invent methods or apparatus more exact than those which have been already employed. Yet, as the philosophical instrument makers of our day accomplish almost miracles in perfection of workmanship, and the impossibilities of one generation become the every day performances of the next, it is unphilosophical to prescribe limits to our progress either in art or science. The precise determination of the temperature of maximum density is beset with difficulties which depend upon the very circumstance which gives to that temperature its great advantage and convenience in practical applications. On either side of the maximum, a very considerable difference of temperature scarcely produces a sensible variation of density or volume. Hence the pro-

blem becomes that of determining a constant by the measurements of almost inappreciable magnitudes. The density is statical and the temperature dynamical, a combination the most advantageous for measurements of the density, but the most disadvantageous for determining a particular temperature as a function of the density.

It is not therefore surprising to find variations of even one or two degrees in the experiments which have been made with more or less care, and by different individuals.

And when we bear in mind that thermometers made by the same person usually give discordant results, and that even the same thermometer suffers in use, displacement and oscillations of its zero point, amounting often to a degree or more, we will rather find cause of wonder in the approximative accordance of the determinations, than in their want of perfect agreement, which serves only to establish the honesty of the witnesses who testify.

The following table, obtained chiefly from determinations compiled by Hällstrom,* comprises nearly all that have been made:

| Observer. | Calculator. | T. | Diff. | Observer. | Calculator. | T. | Diff. |
|---|---|---|---|---|---|---|---|
| Delue .... | Biot..... | 3.42 | — 0.58 | Hope..... | Hope..... | 3.33 | —0.67 |
| Do..... | Ekstrand ... | 3.60 | — 0.40 | Do..... | do..... | 3.88 | —0.11 |
| Do..... | Paucker.... | 1.76 | — 2.24 | Do..... | do..... | 4.16 | +0.16 |
| Do..... | Hällstrom... | 1.76 | — 2.24 | Tralles.. | Tralles..... | 4.35 | +0.35 |
| | | | | Hassler .. | Hassler..... | 4.35 | +0.35 |
| Dalton.... | Dalton..... | 2.22 | — 1.78 | Do..... | do..... | 4.11 | +0.11 |
| Do..... | Biot..... | 4.35 | + 0.35 | Hällstrom | Hällstrom.. | 4.34 | +0.34 |
| Gilpin .... | Young ..... | 3.89 | — 0.11 | Do..... | do..... | 3.87 | —0.13 |
| Do..... | Biot..... | 3.89 | — 0.11 | Do..... | do..... | 4.165 | +0.16 |
| Do..... | Eytelwein.. | 2.59 | — 1.41 | Do..... | do..... | 3.897 | —0.103 |
| Do..... | Walbeck ... | 0.44 | ? | Muncke.. | Muncke..... | 3.5 | —0.5 |
| Do..... | Hällstrom... | 3.82 | — 0.18 | Do..... | do..... | 3.78 | —0.22 |
| Schmidt.. | Eytelwein.. | 2.91 | — 1.09 | Do..... | Hällstrom.. | 3.94 | —0.06 |
| Do..... | Hällstrom.. | 8.63 | ? | Do..... | do..... | 3.82 | —0.18 |
| Charles.. | Biot..... | 3.99 | — 0.01 | Do..... | do. ..... | 4.13 | +0.13 |
| Do..... | Paucker.... | 3.88 | — 0.12 | Do..... | do..... | 3.81 | —0.19 |
| L. Gineau. | L. Gineau.. | 4.44 | + 0.44 | Stampfer. | do..... | 3.93 | —0.07 |
| Bischoff.. | Bischoff.... | 4.06 | + 0.06 | Do..... | do..... | 3.63 | —0.37 |
| Ekstrand . | Ekstrand.... | 3.60 | — 0.40 | Despretz . | Despretz.... | 4.00 | —0.00 |
| Do..... | do..... | 3.90 | — 0.10 | Do..... | do..... | 3.987 | —0.013 |
| Rumford.. | Rumford ... | 4.38 | + 0.38 | Do..... | do..... | 4.007 | +0.007 |
| Do..... | do..... | 3.47 | — 0.53 | Rudberg.. | Rudberg.... | 4.02 | +0.02 |

The temperatures are given in degrees centigrade; and the column marked *Diff.* is obtained by taking the differences between each observation and 4° centigrade, which may be considered the mean of the more probable observations.

91. The remark contained in the last article concerning the variation of the zero point of thermometers, is based upon the following facts: MM. Arago and Gay Lussac observed (in 1817) that the zero of the thermometer in the cellar of the observatory of Paris had risen 0.38. This want of constancy various observers

* See Ann. de Chim. de Phys. t. 28, p. 56.

have since verified; and M. Despretz, who has devoted particular attention to the subject, has shown that the variation, though ascending for several years, suffers oscillations; and that, contrary to the general opinion, the zero, when it has attained its maximum elevation, and even after many years, still continues to oscillate about a mean point.*

From his valuable memoirs, I have extracted the following results, and arranged them in tabular form:

| Thermometer. | No. 1. | No. 2. | Thermometer. | No. 3. | No. 4. | No. 5. |
|---|---|---|---|---|---|---|
| Date. | Zero. | Zero. | Date. | Zero. | Zero. | Zero. |
| Aug. 30, 1832 | 0°. C. | 0°. C. | Nov. 9, 1832 | 0°. C. | 0°. C. | 0°. C. |
| Sept. 3, 1832 | 0.11 | 0.03 | After boiling... | —0.31 | —0.36 | — 0.06 |
| Sept. 5, 1832 | 0.14 | 0.05 | Nov. 11, 1832 | —0.20 | —0.13 | 0.18 |
| Oct. 6, 1832 | 0.19 | 0.13 | Nov. 21, 1832 | —0.04 | —0.10 | 0.19 |
| Nov. 8, 1832 | 0.20 | 0.18 | Dec. 1, 1832 | 0. | —0.03 | 0.25 |
| Dec. 3, 1832 | 0.22 | 0.20 | April 7, 1833 | 0.08 | 0.13 | 0.36 |
| Jan. 5, 1833 | 0.22 | 0.20 | April 4, 1834 | 0.08 | 0.03 | 0.40 |
| April 7, 1833 | 0.29 | 0.22 | July 25, 1834 | 0.08 | 0.10 | 0.42 |
| April 8, 1834 | 0.37 | 0.38 | April 17, 1835 | 0.27 | 0.21 | 0.46 |
| April 20, 1834 | 0.35 | 0.31 | Oct. 2, 1835 | 0.24 | 0.24 | 0.54 |
| April 17, 1835 | 0.37 | 0.35 | Sept. 4, 1836 | 0.30 | 0.24 | Broken. |
| Oct. 2, 1835 | 0.42 | 0.39 | Dec. 5, 1836 | 0. | —0.07 | |
| Oct. 29, 1835 | 0.42 | 0.42 | Dec. 5, 1836 | —0.06 | —0.12 | After boiling. |
| Sept. 21, 1836 | 0.42 | 0.42 | | | | |
| Feb. 5, 1837 | 0.46 | 0.45 | Jan. 4, 1837 | 0.08 | —0.10 | |
| Feb. 9, 1837 | 0.47 | 0.45 | Jan. 22, 1837 | 0.20 | 0.10 | Before boiling. |
| Feb. 21, 1837 | 0.46 | 0.45 | | | | |
| June 4, 1837 | 0.44 | 0.45 | Jan. 22, 1837 | 0.12 | —0.13 | After boiling. |
| June 23, 1837 | 0.42 | 0.42 | | | | |

The sensibility of the thermometers was such, that they could be read to the hundredths of degrees with accuracy. The total variation of No. 1 was 0°.47, and of No. 2 it was 0°.45; it was ascending from August, 1832, to February, 1837, a period of four years and five months. In the same interval, two other thermometers (No. 6 and No. 7) varied respectively 0°.23 and 0°.30; while another (No. 8) varied between 23d November, 1832, and 20th March, 1837, to the extent of 0°.57.

These thermometers were made in 1832, and served for experiments during the interval, which is the cause why the variation was sometimes even retrogade. M. Despretz considers it established by his observations, of which he professes to have made many which are not yet published, that the zero points of thermometers are sensibly affected by the atmospheric variations, and that they *fall in summer* and *rise in winter;* while thermometers kept in places where the temperature is constant ascend uniformly, without oscillations, to a maximum at which they remain stationary. The preceding experiments, and particularly those made in

*See Ann. de Chim. de Phys., t. 64, p. 312, 1827.

1836 and 1837, with Nos. 3 and 4, establish the fact, that high degrees of heat cause the zero point to fall, and that it ascends, on the contrary, if subjected to low temperatures; also, that the oscillation may amount to even a half degree of the centigrade thermometer, or a whole degree nearly of Fahrenheit. It has therefore been justly remarked by M. Pouillet, (Phys. 1e part. chap. 1,) that, though ignorant of its cause, we can have no doubt of the fact itself, and that therefore all observers should verify the graduations of their thermometers. It does not appear that the observers who have undertaken to fix the temperature of the maximum density of water paid sufficient attention to the verification of the zero point, or origin of measurement; and certainly linear measurements are but half made when the position of only one of the ends of a line is determined. It is on this account that I attach higher value and attribute greater accuracy to the experiments of M. Despretz than to any others, and that I have chosen 4° centigrade, the mean of his results, as the most probable value. M. Hällstrom, it is true, has taken a great deal of mathematical pains to calculate, by the refined though laborious method of least squares, the probable mean of the more accurate experiments made without regard to the variation of the zero point. And his calculations have served to show that the point of maximum density lies somewhere between the limits of 4°.34 and 3°.87 centigrade, which differ 0°.47 centigrade, or 0°85 Fahrenheit; the mean 4°.1 differs slightly from the determination of M. Despretz. Hällstrom himself comes to the conclusion, from his calculations, that the temperature of maximum density cannot be determined without leaving upon its value an uncertainty of one-quarter of a degree centigrade. And by a discussion of the probable errors he proves that, for values smaller than 3°.678 centigrade, or greater than 4°.583 centigrade, the probability is infinitely small, and that they must therefore be rejected. This distinguished philosopher has clearly shown in his valuable memoir* the necessity of discussing, by calculations of the greatest rigor, experiments made to determine a value that depends upon variations of density which may be considered infinitely small; but the beautiful method of least squares becomes inexact when applied to observations, whose errors are so great that their squares become large quantities, as well as the errors themselves.

92. M. Despretz performed his experiments in two different ways:† one, the method of Deluc, by employing a water thermometer; the other, a modification of the method of Tralles and Hope, by observing thermometers placed at different levels in the same vessel of water, the particles of which arrange themselves in strata according to their densities. To this method the objection has been urged, that it depends upon motion to be produced by the

* Ann. de Chim. et de Phys., t. 23.
† See Ann. de Chim. et de Phys., t. 70, p. 1.

mechanical action of forces too feeble near the maximum to overcome the resistance opposed by the cohesion of the particles of water. And this objection is sustained by the discrepancy of the results; thus, Hope obtained 3°.33, 3°.88, and 4°.16; and Rumford, 4°.38 and 3°.47. Hällstrom rejects this method, as rather calculated to show the existence of a maximum several degrees above the zero point than to determine the precise degree with accuracy. He however remarks, that the mean 3°.88 of the observations is approximatively exact; and that, if a great many observations be made by different persons, a probable compensation of their errors would take place, and a mean result of considerable accuracy would be obtained. M. Despretz endeavors to overcome the objection mentioned, by suspending the vessel of water, and causing a vibratory motion of its particles by repeated gentle tapping with a stick; he thus obtains the mean result 3.°987; which, while it serves to confirm the determination 4°.000 of this first method, yet does not, in my opinion, prove that he has succeeded in doing away entirely with the objection to this hydrostatical method of Hope and Tralles; for his result is but the mean of observations whose errors compensate each other. This is proved by the curves, which otherwise should intersect nearly or exactly in a single point.

But it is to the observations of M. Despretz, made according to the method of Deluc, and which he has discussed by a very ingenious, graphic method, as well as by means of Lagrange's formula for interpolation by logarithms, that I would give the preference over all others. The method of Deluc, as it is the simplest, so also does it appear to be the most accurate; and the objections of Hällstrom are not, in my opinion, sufficient to show that its results are uncertain. The error of capillarity may be considered a constant, which is not a factor of the variations of volume by temperature, and which therefore disappears by differentiation from the equation of the maximum value of the density. And this constant might be rendered almost nothing, and certainly inappreciable in the observations themselves, by experimenting with tubes of greater diameter and proportionally larger bulbs. The graphic method of M. Despretz consists in representing the apparent dilatation of water by a curve of which the ordinates are the observations and the corresponding temperatures the abscissas. To this curve he draws a tangent parallel to the straight line which represents the dilatation of the glass of which the thermometer is constructed. Then it is evident that the abscissa of the point of tangency will represent the temperature of maximum density. If the law of the dilatation of water was known and expressed by a formula of perfect rigor, nothing would be easier than to determine this point of tangency with the utmost degree of exactness; for it would be merely requisite to make the differential coefficient of the curve equal to the coefficient of dilatation of the glass, and eliminate the corresponding value of $x$. In the absence of such knowledge, M. Despretz determines the point by regarding the curve as a parabola, from which it does not differ sensibly for a considerable extent on either side of that point; and he then avails

himself of the property, that a diameter bisecting chords parallel to a tangent, cuts the parabola in the point of tangency. A member of the committee of the Academy, charged with the examination of the paper of M. Despretz, having informed him that they would have attached greater value to his researches if they had been discussed analytically, he undertook to calculate them by Lagrange's formula of interpolation

$$y^x = X\,y + X_1\,y_1 + X_2\,y_2 + X_3\,y_3 + X_4\,y_4 + \text{etc.} \quad - \quad (32).$$

and obtained results exactly accordant with those of his graphic method.* In this formula

$$\left.\begin{aligned} X &= \frac{(x-a_1)\,(x-a_2)\,----\,(x-a_n)}{(a-a_1)\,(a-a_2)\,----\,(a-a_n)}; \\ X_1 &= \frac{(x-a)\,(x-a_2)\,----\,(x-a_n)}{(a_1-a)\,(a_1-a_2)\,----\,(a_1-a_n)}; \\ X_n &= \frac{(x-a)\,(x-a_1)\,----\,(x-a_{n-1})}{(a_n-a)\,(a_n-a_1)\,----\,(a_n-a_{n-1})}. \end{aligned}\right\} \quad - \quad - \quad (33).$$

The manner in which M. Despretz has applied the method of curves to the results of each of his two methods of observation, constitutes, in my opinion, one of the chief excellencies of his valuable memoir. And although the rigor of analysis entitles it to the highest regard, and renders it indispensable in the determination of the constants of nature, yet graphic methods possess peculiar advantages in physical inquiries, which the symbols of analysis never present; the one calls in the aid of the eye and the judgment, the other addresses itself to the mind, in the language of abstract relations of number.

As I have presumed to dissent from the views of the committee of the Academy with regard to the value of graphic methods, I may be permitted to cite high authority to sustain me. No one, who will take the pains to read the valuable paper of Sir John Herschel on the orbits of *double stars*,† can fail to admire the example presented by that memoir of the use of graphic methods. He there shows that the graphic process often determines *mean* results more accurately than formulas of interpolation; that it eliminates errors from the very observations themselves, correcting particular discrepancies by the general law of the whole mass of observations; and that, to use his own language, "in following the graphic process we have a conviction, almost approaching to moral certainty, that we cannot be misled." There is but one of our analytical methods at all analogous to this in its advantages, that of the least

* See Ann. de Chim. et de Phys., t. 73, p. 296.
† See Trans. Astr. Soc., vol. v, p. 1.

squares, which depends upon the principle that small errors are more probable than large ones; and, therefore, that, in the most probable observations, the errors do not compensate, but the sum of their squares is a minimum.

When the mean curve is not of any known form, it becomes difficult to discuss its properties; but for a limited arc, if free from singular points, it is proved, by the theory of osculations, that we may assume the curve to be identical with a parabola which coincides with it so nearly that the difference is inappreciable. It is thus, that the orbits of the planets are assumed to be conic sections, notwithstanding the discrepancies presented by perturbations. And this is equivalent to the analytical method of representing phenomena by formulæ, such as that employed by Biot, and all who have since attempted to discuss analytically observations of the law of dilatation, and of the temperature of the maximum density of water?* The method of M. Despretz, of determining the point of tangency by the bisection of parallel chords, is certainly accurate, for it is nearly equivalent to the familiar and general mode of determining the equation of the tangent to a curve, by supposing a secant to vary until the points of secancy coincide; and, as the equation

$$y = a + bt + ct^2 + dt^3 + et^4 \ldots + pt^n \quad - \quad - \quad - \quad (35),$$

is the general equation of a parabola of the $n$th order, it follows that, by using the method of Despretz, which assumes the curve of dilatation to be the common parabola, whose equation is

$$y = a + bt + ct^2 \quad - \quad - \quad - \quad - \quad - \quad - \quad (36),$$

we simply omit to take account of the terms of the third order in the formula

$$y = a + bt + ct^2 + dt^3 \quad - \quad - \quad - \quad - \quad - \quad (37),$$

which Biot has shown to represent the law of dilatation of liquids with accuracy, and which is the equation of the parabola of the third order.

Moreover, in judging of the exactness of our analytical methods, it should be borne in mind that the problem of interpolation is indeterminate, unless we know the law of the phenomena. For it consists in finding a function which shall have several given successive values for the corresponding values of the independent variable, and these conditions are fulfilled by many different functions, as is shown by the possibility of drawing various curves through a given number of points, and also in a very elegant manner by Lagrange's formula of interpolation. The numerator of the expression for the value of X of equations (33)

$$(x - a_1)(x - a_2) \quad - \quad - \quad - \quad - \quad (x - a_n)$$

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*See Biot, Traité de Physique, t. I. p. 210.

is not the only function which vanishes when $x$ becomes equal to $a_1, a_2 \ldots a_n$. Lagrange has given the formula

$$u = A \sin. \frac{\pi x}{a} + A_1 \sin. \frac{2\pi x}{a} + A_2 \sin. \frac{3\pi x}{a} + \text{etc.},$$

as one which becomes 0, for each of the values $x$ of the series $a$, $2a$, $3a$, &c., and which may serve for the interpolation of periodical functions. And the expression

$$X = \frac{\sin. m(x - a_1) \sin. n(x - a_2) - - - \sin. k(x - a_n)}{\sin. m(a - a_1) \sin. n(a - a_2) - - - \sin. k(a - a_n)}$$

is one which serves for any values of $m$, $n$, and $k$.

Similar functions may likewise be obtained for the values $X_1$, $X_2$, &c., of the equation

$$X_n = \frac{\sin. \alpha(x - a) \sin. \beta(x - a_1) - - - - \sin. \phi(x - a_{n-1})}{\sin. \alpha(a_n - a) \sin. \beta(a_n - a_1) - - - - \sin. \phi(a_n - a_{n-1})}$$

Hence it follows, that neither graphic nor analytical methods can give temperatures of maximum density with rigid exactness, so long as we are ignorant of the exact nature of the physical laws of the dilatation of liquids, though we can obtain values with all requisite approximative accuracy.

93. I have felt an interest in this matter sufficient to have induced me to apply the method of least squares, which Hällstrom seems to consider the only admissible one, to the experiments of M. Despretz. I thus obtain 4°.223, instead of 4°, as the probable determination; and this differs but 0°.123 from the mean which Hällstrom has deduced from the mass of observations made by different persons. The method I have followed is given in the next chapter.

*New analytical discussion of the observations of M. Depretz.*

94. As the method of least squares loses its advantage, and becomes inaccurate, when any of the extreme errors of calculation are very great, by giving to these errors an influence proportional to their squares,* and as the numerical calculations become very long and tedious when the method is applied directly to a large number of results, I have so combined the data of each set of the experiments of M. Depretz as to obtain mean equations, from which I then determine the temperature of maximum density of

*See Bowditch's Notes to Laplace, Mécanique Céleste, vol. ii, p. 434.

water by differentiation and the use of least squares. By following this method, I greatly abridge the labor of calculation, and the result is more accurate than if obtained directly from the observations themselves. Any great error is exposed, and that observation, or set of observations, may be rejected, or their probable error may be computed, and the corresponding correction applied; I prefer to reject them.

In the method I employ to obtain the unknown constant coefficient of Biot's formula, (37,) the mean value of $a$ is given for each experiment by six determinations, that of $b$ by two, and $c$ by one only. Thus, greater accuracy is obtained where most required, and errors of observation are rendered apparent, particularly in the value of $a$, by discordant results.

Logarithmic computation becomes inaccurate when the numbers are very large. I have, therefore, found it necessary to employ the laborious method of actually performing all the multiplications and divisions. To avoid those accidental errors to which such arithmetical operations are peculiarly liable, the calculations were also made at my request by my brother; thus, mistakes were detected and corrected by differences in our calculations; nor have I failed to test even the accordant results by the approximative verifications which logarithms afford. Such care, in my opinion, should always be bestowed on determinations of the constants of Nature.

95. The formulas I have employed are usually contained in the works which treat of the calculus of finite differences,*

$$\left.\begin{aligned} v &= at + bt^2 + ct^3 + \text{etc.} \\ v_1 &= at_1 + bt_1^2 + ct_1^3 + \text{etc.} \\ v_2 &= at_2 + bt_2^2 + ct_2^3 + \text{etc.} \\ v_3 &= at_3 + bt_3^2 + ct_3^3 + \text{etc.} \end{aligned}\right\} \quad - - - - - \quad (38);$$

then if we put

$$\frac{v - v_1}{t - t_1} = f(v); \quad \frac{v_1 - v_2}{t_1 - t_2} = f(v_1); \quad \frac{v_2 - v_3}{t_2 - t_3} = f(v_2); \text{ etc.}$$

we shall have

$$\left.\begin{aligned} f(v) &= a + b(t + t_1) + c(t_2 + t\,t_1 + t_1^2) + \text{etc.} \\ f(v_1) &= a + b(t_1 + t_2) + c(t_1 + t_1 t_2 + t_2^2) + \text{etc.} \\ f(v_2) &= a + b(t_2 + t_3) + c(t_2^2 + t_2 t_3 + t_3^2) + \text{etc.} \end{aligned}\right\} \quad - \quad (39),$$

and analogously subtracting each of the two last equations from that which precedes, and dividing by the factor of the first term, we obtain

$$\left.\begin{aligned} f_2(v) &= b + c(t + t_1 + t_2) + \text{etc.} \\ f_2(v_1) &= b + c(t_1 + t_2 + t_3) + \text{etc.} \end{aligned}\right\} \quad - \quad - \quad - \quad (40).$$

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*See Lacroix, Calc. Diff., vol. 3, p. 32, 4to; Paris, 1819.

From which, lastly:

$$f_3(v) = c \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad (41).$$

Hence it is evident that we shall obtain from four equations of condition (38) *one* value of $c$, two values of $b$, and six values of $a$; for each of the values of $b$ gives a value of $a$ in the equations (39.) And since three equations of condition determine the values of three unknown quantities, our fourth equation serves as a test upon the accuracy of the observations, and will give very discordant values of the coefficients, if they are not free from considerable error. Thus, in the third experiment, they lead to two widely different values for $b$, or, if equal values are assigned, to absurdity; I have therefore rejected it entirely. It is not unlikely that I may have copied the observations incorrectly in my notes from the memoir of M. Despretz, which is not now within my reach, or that they are printed incorrectly.

96. The following are the observations of M. Despretz, which I have submitted to calculation, and arranged for brevity in tabular form. They are those to which he has himself applied Lagrange's formula of interpolation.

| Experiment I. | | Experiment II. | | Experiment III. | | Experiment IV. | |
|---|---|---|---|---|---|---|---|
| Temp. | Volume. | Temp. | Volume. | Temp. | Volume. | Temp. | Volume. |
| ° C. | | ° C. | | ° C. | | ° C. | |
| 7.48 | 92759.03 | 7.18 | 92757.39 | 5.91 | 92745.69 | 6.33 | 92754.46 |
| 5.90 | 92753.29 | 5.69 | 92752.60 | 4.73 | 92743.28 | 5.68 | 92752.72 |
| 3.74 | 92750.83 | 4.04 | 92750.64 | 3.23 | 92743.33 | 5.21 | 92751.86 |
| 2.17 | 92753.12 | 2.59 | 92752.07 | 1.86 | 92746.11 | 3.87 | 92750.84 |

The numbers in the vertical columns of volume express divisions of the graduated scale contained both in the reservoir and the tube; to which the correction of dilatation for the particular glass has been applied, so that the volumes are absolute. A second tube gave the following analogous results:

| Experiment V. | | Experiment VI. | | Experiment VII. | | Experiment VIII. | |
|---|---|---|---|---|---|---|---|
| Temp. | Volume. | Temp. | Volume. | Temp. | Volume. | Temp. | Volume. |
| ° C. | | ° C. | | ° C. | | ° C. | |
| 5.91 | 61842.54 | 7.18 | 61841.89 | 7.48 | 61843.01 | 7.77 | 61857.52 |
| 4.93 | 61841.00 | 5.69 | 61838.64 | 5.90 | 61839.82 | 6.05 | 61852.76 |
| 3.23 | 61841.01 | 4.04 | 61837.39 | 3 74 | 61837.52 | 4.27 | 61850.75 |
| 1.86 | 61842.77 | 2.59 | 61838.30 | 2.47 | 61839.04 | 1.41 | 61854.34 |

It appears that the temperatures of experiments Nos. 1, 2, 3, and

7, 6, 5, are identical; but while the volumes of No. 5 do not differ, except by a few units, from those of No. 6 and No. 7, those of No. 3 vary greatly from the volumes of No. 1 and No. 2; this also proves the propriety of rejecting No. 3 as incorrect. To the identity I have mentioned, there is one exception—the last temperature of No. 1 is 2°.17, while that of No. 7 is 2°.47. The values of $a$, which I have obtained for the observations of No. 1, give somewhat discordant results; while those of No. 7 accord very closely. I therefore tried the effect of supposing 2.17 to have been, by an error of printing or copying, substituted for 2.47, but the discrepancy became much greater, and affected the values of $b$ to an extent which rendered it necessary to abandon the hypothesis. This fact serves to show the accuracy of the method employed, as well as of the observations themselves; for the error of three-tenths of a degree rendered it impossible to obtain values at all alike, even for the coefficient of the second power of the temperature.

97. The calculations are too long to be given in full in this paper, nor would any one desire to follow them; their results may, however, be embodied in tables, which any one may test by particular examples, who is so disposed. To render the numbers smaller, I subtract each temperature from 4°; which cannot affect the result of the maximum density, as is evident from the fact that it is equivalent to a simple change of the origin of co-ordinates. By substituting the numerical values in the formulas of article 95, I obtain:

| No. | $f(v_0)$ | $f(v_1)$ | $f(v_2)$ | $f_2(v)$ | $f_2(v_1)$ | $f_3(v)$ |
|---|---|---|---|---|---|---|
| 1 | 4.3037974 | 1.1342590 | —1.4585987 | 0.8591439 | 0.6951091 | 0.02919676 |
| 2 | 3.2147651 | 1.1878788 | —0.986217 | 0.6455052 | 0.6948697 | —0.0107549 |
| 3 | 2.0423729 | —0.0333333 | —1.1029197 | 0.7745172 | 0.3726788 | 0.9921688 |
| 4 | 0.2670707 | 0.1829787 | 0.7611940 | 0.0750821 | —0.3194559 | 0.1603813 |
| 5 | 1.3050847 | —0.0066666 | —1.2846715 | 0.4894594 | 0.4452978 | 0.01090401 |
| 6 | 0.7575757 | —0.6275862 | 0.78213507 | 0.4468264 | 0.4489558 | 0.0014291 |
| 7 | 2.0189873 | 1.0648141 | 0.8491620 | 0.2551265 | 0.0628723 | 0.0383741 |
| 8 | 1.1292134 | 1.2552447 | 0.2500000 | 0.5138918 | 0.5014984 | —0.0072054 |

And from these I deduce the coefficients $a$ and $b$, by similar substitution.

| No. 1. | No. 2. | No. 4. | No. 5. | No. 6. | No. 7. | No. 8. |
|---|---|---|---|---|---|---|
| *b.* | *b.* | *b.* | *b.* | *b.* | *b.* | *b.* |
| 0.70065687 | 0.69831176 | — 0.7620983 | 0.4690689 | 0.44636909 | 0.05865121 | 0.5119463 |
| *a.* | *a* | *a.* | *a.* | *a.* | *a.* | *a.* |
| — 0.1175600 | 0.0112790 | 1.3719340 | 0.0059497 | — 0.0188234 | 0.84645848 | — 0.0237511 |
| — 0.1207432 | 0.0112618 | 1.3719449 | 0.0059495 | — 0.0188234 | 0.84645861 | — 0.0237082 |
| — 0.1078802 | — 0.0087375 | 1.3719635 | 0.0059504 | — 0.0251579 | 0.84645791 | — 0.0237304 |
| *b.* | *b.* | *b.* | *b.* | *b.* | *b.* | *b.* |
| 0.70065648 | 0.69831127 | — 0.7621079 | 0.4690682 | 0.4463691 | 0.05865118 | 0.5119463 |
| — 0.1175570 | 0.0112398 | 1.3719726 | 0.0059497 | — 0.0188236 | 0.84645790 | — 0.0237511 |
| — 0.1207432 | 0.0112629 | 1.3719819 | 0.0059356 | — 0.0188234 | 0.84645798 | — 0.0237082 |
| — 0.1079105 | — 0.0085583 | 1.3719738 | 0.0059481 | — 0.0251579 | 0.84645860 | — 0.0237304 |
| 0.700656675 | 0.698311525 | — 0.7621032 | 0.46906855 | 0.446369095 | 0.58651195 | 0.5119463 |
| — 0.1153990 | 0.00463128 | 1.3719618 | 0.0059472 | — 0.0209349 | 0.84645825 | — 0.0237299 |

The two last horizontal columns contain the mean values of the numbers above.

By differentiation, the formula (37) gives

$$\frac{dv}{dt} = a + 2bt + 3ct^2 \quad - \quad - \quad - \quad - \quad - \quad - \quad (42);$$

which, for the maximum, becomes equal to zero. Hence, by substitution and reduction, after passing again to the primitive origin of abscissas, we obtain in degrees centigrade from

$$\left.\begin{array}{l} \text{No. 1, } 0 = 6.89129888 - 2.10203559\,t + 0.08759028\,t^2; \\ \quad 2,\ 0 = 5.07488608 - 1.1385049\ \ t - 0.0322647\ \ t^2; \\ \quad 4,\ 0 = 2.9734386\ \ - 2.3249448\ \ t + 0.4811439\ \ t^2; \\ \quad 5,\ 0 = 4.28188808 - 1.19983334\,t + 0.03271203\,t^2; \\ \quad 6,\ 0 = 3.61861466 - 0.92703659\,t + 0.0042873\ \ t^2; \\ \quad 7,\ 0 = 7.38051065 - 2.0940023\ \ t + 0.1151223\ \ t^2; \\ \quad 8,\ 0 = 3.7259813\ \ - 0.850963\ \ \ t - 0.0216162\ \ t^2; \end{array}\right\} (43.)$$

And these are the *mean* equations of condition to which (as stated in art. 94) the method of least squares is to be applied, instead of using the actual observations themselves.

98. The method of least squares gives:

$$\begin{array}{l} \text{No. 1, } 0 = -14.485755070971392 + 4.418545213488288\ t - 0.184596484695218\ t^2; \\ \quad 2,\ 0 = -\ 5.777694549121792 + 1.29619840732491\ \ t + 0.03673351904708\ \ t^2; \\ \quad 5,\ 0 = -\ 5.137552076532587 + 1.4386008690995556\,t - 0.039248984213080 2\,t^2; \\ \quad 6,\ 0 = -\ 3.3545381949244094 + 0.8593968391988281\,t - 0.003974483972307\ t^2; \\ \quad 7,\ 0 = -\ 15.45480627627449 + 4.3849081620529\ \ t - 0.2410863609812 9\ t^2; \\ \quad 8,\ 0 = -\ 3.1706722249919 + 0.724084420669\ \ t - 0.0183945864006\ \ t^2; \end{array}$$

And from these we have the final equation of the second degree

$$0 = -47.381068828942317 + 13.1217289118325818\,t - 0.4505473812254652\,t^2.$$

From which I deduce 4°.223 as the value of $t$, or the temperature of the maximum density of water.

This differs two-tenths of a degree from the determination of M. Despretz, a quantity which but serves to show the accuracy of his experiments, and of the calculations by the method he employed. Since 4°.223 centigrade are equivalent to 39°.601 Fahrenheit, and it is impossible to read to the thousandth of a degree, I conclude that 39°.6 Fahrenheit is the temperature of the maximum density given by the most exact researches. For ordinary practical purposes, we may employ 39°.5 Fahrenheit, or 4° centigrade. In the final calculations, I have taken no account of No. 4, by reason of the great probable error by which the mean equation is effected, which renders it proper that it should be discarded.

It is interesting to know that the temperature 39°.4 Fahrenheit, adopted by the late Mr. Hassler for the construction of the standard weights and measures of the United States, differs but two-tenths of a degree from the result of the preceding calculation; a

difference which could not produce any appreciable errors in those standards.

*On the dilatation of mixtures of alcohol and water.*

99. On this subject, perhaps the most difficult and extensive connected with the present inquiry, my researches have not led me to many important results, nor assumed a shape sufficiently definite to be included in this report. Neither have I made any experiments; because, to be properly made, they should be definite questions propounded to nature as the witness, with particular objects in view. Otherwise, experiments become a mere waste of time and money. It is but a few days since I have received from France and Germany the papers which contain the results of similar researches made for the governments of those countries; the labors of Gilpin and Blagden, for the British government, have been in my possession from the time nearly at which I commenced these investigations in June last; and I have also collected, from the various journals and transactions of scientific societies, much valuable original matter. To discuss this mass of information thoroughly, requires more time than I have yet been able to command; but, as I devote a considerable portion of my labor to this branch of the inquiry, I hope at an early day to be able to report the complete and final results. The method of discussion I follow is at first graphical, that the eye may aid in seizing the laws of the phenomena; subsequently, analysis serves to give more exact determinations.

An interesting result at which I arrived, soon after I commenced my investigations, is presented by the fact that, for all practical purposes, liquors containing more than thirty per cent. of alcohol may be considered to expand uniformly for equal increments of temperature of the mercurial thermometer. This law becomes more exact the greater the per cent. of alcohol contained, and the error is within the limits of errors of observation, if that per cent. exceed ninety. I was first led to this conclusion by the consideration of the circumstance that the first differences are nearly constant, and it is fully verified by the graphic process. A glance at plate II will be sufficient to convince any one of the truth of this law; for it shows that the parabola, which represents the dilatation of very dilute aqueous solutions of alcohol, gradually passes into a straight line; I have drawn the curves on a large scale, of which plate II is merely a reduced copy. The researches of Gilpin and Blagden furnish the data which I have employed in this determination.

Within a few days, I have found, in reading the report of Tralles to the Prussian government, that he confirms the law I have just given, as far as it is applicable to absolute alcohol; for, in a note by Gilbert,* is stated that Tralles "found from experiments made with absolute alcohol, that between — 15° and + 15°

*See Gilbert's Annalen der Physik, Jahrg. 1811, St. 6, S. 364.

Fahrenheit, it expands as uniformly by heat as mercury or air. The opinion hitherto entertained, that alcohol obeys a different law of dilatation, is therefore to be attributed to the water with which it is generally mixed."

In plate II, figs. 5, 6, and 7, I have drawn tangent lines, to enable the eye to judge of the curvature. In fig. 8, the tangent becomes coincident with the curve itself, which therefore has passed into a straight line.

I shall defer further remarks upon the subject of dilatation to a future occasion, when I shall have fully investigated the subject; and I feel that they may now be properly excluded, as this report has attained a length much beyond what I had supposed would be necessary. I will simply add, that I propose to make a series of experiments of verification with thermometers constructed of different proportions of alcohol and water, a method which I regard as both the simplest and most exact.

*On the different proofs of spirits.*

100. It appears that, in nearly all countries, there is established in trade a system of "*proofs*," or commercial conventional strengths, at which spirituous liquors are bought and sold. And were not these "proofs" interfered with and modified by particular legislation, it is not unlikely that there would arise uniform commercial standards throughout the world. For exportation, it is always desirable that liquors should be as strong as possible to avoid paying freight on mere water of dilution; and water, which may be found any where, should be added rather by the consumer than the producer; hence, each kind of spirits will, if trade be left to take its natural course, be furnished to foreign markets of but one degree of strength, which will be the maximum attainable without injury to the quality. Of some varieties of ardent spirits, as for instance, cognac brandy and the *Kirschwasser* (cherry brandy) of the Black forest, the value depends upon the flavor, and the strength is a subordinate matter; nor could such liquors generally be highly rectified without injury to their flavor. But, as a general rule, the value of a liquor depends upon and is proportional to the strength, or the per cent. of alcohol it contains.

101. The necessity of proving in trade the strength of ardent spirits, that the buyer may know how much water he is bargaining for, has led to the use of hydrometers; and I cannot better illustrate the value of this little instrument than by translating a passage from the writings of the Baron Charles Dupin: "The Spaniards, whose strong wines are very well suited for distillation, endeavored to compete with us in the manufacture of brandy. But, neglecting to measure the degree of concentration with the hydrometer, they merely let fall from a certain height a drop of oil into the brandy. The deeper this drop sank, the stronger they concluded the liquor to be. But so rough a method constantly led them into error.

They therefore furnished to the foreign markets brandies of very unequal degrees of strength, which gave their production a very bad reputation, and they were even compelled to sell to us at reduced prices. Then, with our hydrometers we easily reduced their brandies to the proper degree of strength, and sold them for the same prices as our own. This commerce with the north of Europe alone, caused us to gain four millions of francs yearly before the revolution. At present, the Spaniards, having learned to use hydrometers, no longer permit us to enjoy this benefit. Hence, it is easily seen what important advantages a very simple little instrument may give to certain nations in commerce and wealth. Such is the practical value of science."*

102. It seems to me that the proper policy to be adopted by governments, in levying duties on ardent spirits, is so to frame their laws and regulations that they may be adapted to, and not in conflict with, the system of strengths which would obtain in commerce if there were no duties to be paid. By so doing, commerce may be facilitated, which otherwise is subjected to considerable inconvenience. Again, as the tastes and habits of the same country vary with time, it appears to me that no one system of commercial proofs can be considered fixed; and therefore legislation should be general, or independent of particular proofs and of the hydrometer used, and so devised that any commercial change may not be hindered, nor require the existing laws to be modified. This can be done by levying duty on the alcohol contained, without regard to the water, which is valueless; nor do I see how it could be otherwise readily accomplished.

103. There seems to be but one degree of proof, or strength, which is common to nearly all countries except England; this is, the "first proof" of the United States, "*die holländische Probe*" of Germany, and the "*preuve d'Hollande*" of France. It marks 19° Cartier, ten per cent. below hydrometer proof of Dycas, and 50 per cent. by volume of the alcoholometer of M. Gay Lussac; and it is therefore composed by measure of equal parts of alcohol and water. When spirits of this degree of strength is briskly agitated in a flask, a series of little bubbles form at the surface, and it is then said to give a "*bead*," or to be of "the Holland proof," or is simply called, in general commerce, proof spirit.

104. In France there are found in commerce other degrees of strength, which are all referred to proof spirit (*preuve d'Hollande*,) as a type. These are called "*esprit trois-cinq*" (spirit three-five;) "*esprit trois-six*," (spirit three-six;) "*esprit trois-sept*," (spirit three-seven;) and so on. These terms signify that three volumes diluted with water to five, six, seven, etc., volumes will then be of the strength of Holland proof, which is the liquor of consumption. But the duties, as I have before stated, are levied by the

*See Géom et Mec. des Arts et Metiers et des Beaux Arts; par M. le Baron Ch. Dupin, t. iii, Dynamie, 7e Leçon.

French government on the proportion of alcohol by volume contained in any spirit, without regard to its commercial name.

105. In England, the laws of the excise seems to have taken precedence, and to have counteracted the influences of general commerce entirely. In the language of Dr. Ure,* "the inquisitorial *regime* imposed by law upon our distilleries might lead a stranger to suppose that our legislators were desirous of repressing, by every species of annoyance, the fabrication of the fiery liquid which infuriates and demoralizes the lower population of these islands. But, alas! credit can be given them for no such moral or philanthropic motive. The necessity of the exchequer to raise a great revenue, created by the wasteful expenditures of the State on the one hand, and the efforts of fraudulent ingenuity on the other, to evade the payment of the high duties imposed, are the true origin of that *regime*. Examinations in distilleries are constantly making by the officers of the excise. There is a survey at 6 o'clock in the morning, when the officers take their accounts and gauges, and make calculations which occupy several hours. At 10 o'clock they again survey, going over the whole premises, where they continue a considerable time, frequently till the succeeding officer comes on duty. At 2 in the afternoon another survey takes place, but not by the same people. At 6 in the evening the survey is repeated; at 10 there comes another survey, by an officer who had not been engaged in any of the previous surveys of that day. He is not relieved until 6 the next morning. In addition to these regular inspections, the distilleries are subject to frequent and uncertain visits from the surveyor and surveyor general. We are never," says Mr. Smith, the eminent distiller of White Chapel, "out of their hands." Such is the excise system of Great Britain. And it was the remembrance of the hardships and severities to which the British excise laws and their violations had led, which gave rise, at any early period of the history of our government, among the Scotch and Irish settlers of Western Pennsylvania, to the insurrection, which is familiarly known as that of the "whiskey boys," in consequence of an act establishing a system of excise with relation to domestic distilled spirits. The policy of Great Britain seems to be regulated rather by the excise than the customs. Hence, her complicated, artificial, and very imperfect system of "over proofs" and "under proofs," is peculiarly her own. Nor has it been imitated, except to a certain limited extent, in our country; in consequence of the adoption of Dycas's Liverpool hydrometer as the standard of the United States.

106. In Great Britain, duty is charged on "*Sikes's hydrometer proof spirit;*" and if a liquor be not of that degree of strength, then, by act of Parliament, a calculation is to be made by Sikes's tables and hydrometer, to obtain the "over proof" or "under proof," which is "the decimal multiplier by which the gauged content of a cask is to be multiplied," and thus increased or diminished so as to

* See Dictionary of Arts and Manufactures, p. 403; London, 1840.

reduce it to hydrometer proof spirit; upon which calculated volume the duty is then to be paid. To determine what constitutes Sikes's hydrometer proof spirit, we have the definition of the act of Parliament; that at 51 degrees of Fahrenheit it weighs twelve-thirteenths of the weight of an equal bulk of water. In decimal fractions 12:13 = 0.923007, which is therefore the specific gravity, if water be taken at the same temperature as unity. This specific gravity, reduced to 59° Fahrenheit, becomes 0.920 nearly; which, by the table of Marozeau* for densities corresponding to the indications of Gay Lussac's alcoholometer, gives 58 per cent. by volume, as the proportion of alcohol in Sikes's hydrometer proof spirit.

107. In the United States, Dycas's Liverpool hydrometer seems to have come into use in the following manner: It was employed in the States at the time of the formation of the federal Union, and was therefore adopted by our government by act of Congress approved August 10, 1790. In that same act I find spirits divided into six classes,† namely: 1st, "distilled spirit of more than ten per cent. below proof, according to Dycas's hydrometer;" 2d, "if more than five and not more than ten per cent. below proof, according to the same hydrometer;" 3d, "if of proof, and not more than five per cent. below proof, according to the same hydrometer;" 4th, "if above proof, but not exceeding twenty per cent. according to the same hydrometer;" 5th, "if of more than twenty and not more than forty per cent. above proof, according to the same hydrometer;" 6th, "if more than forty per cent. above proof, according to the same hydrometer." By act of Congress, approved March 3, 1791, it is enacted‡ that these six "several kinds of proof shall be distinguished, corresponding with the order in which they are mentioned, by the words "first proof," "second proof," "third proof," "fourth proof," "fifth proof," "sixth proof;" "and that it be the duty of the Secretary of the Treasury to provide and furnish to the officers of inspection and of the customs proper instruments for ascertaining the said several proofs." This system, thus established by law, has not since been disturbed; and although the Secretary of the Treasury is, by act of Congress approved January 10, 1825, "authorized to adopt and substitute such hydrometer as he may deem best calculated to promote the public interest, in lieu of that now prescribed by law, for the purpose of ascertaining the proof of liquor," no change has taken place. And this may perhaps be owing chiefly to the fact, that no appropriation has ever been made to enable the Secretary of the Treasury to carry this law into effect, by causing proper investigations to be made by competent persons. At the time, when Dycas's hydrometer was adopted by our government, it was perhaps the most perfect instrument known; but this superiority it has long since lost, and it

*See Encyclopedia of Chemistry, by Messrs. Booth and Boye—art. Alcoholometer, page 96. Philadelphia, 1844.

†See Laws of the United States, vol. 2, page 176, chap. 66, sec. 1.

‡See Ibid, vol. 2, page 215, chap. 89, sec. 37.

is now as far inferior to the centesimal alcoholometer of M. Gay Lussac as it was then superior to the instrument of Clarke, which it superseded. I do not consider the hydrometer of Sikes more perfect than that of Dycas; and, indeed, it is more uncertain, if constructed by ordinary workmen, in consequence of the fact that the weights are immersed.

108. The language "ten per cent. *above* proof," "twenty, thirty, forty, etc., per cent. *above* or *below* proof," for Dycas's hydrometer, is not, as would be generally supposed, synonymous with the corresponding language, "ten per cent. *over* or *under* proof," for Sikes's hydrometer. It varies in signification, not only because the proofs of these hydrometers do not correspond to the same strength of spirits, but also materially in itself. The "over proof" and "under proof" of Sikes is the quantity per cent. by which the guaged contents of a cask is to be multiplied, to reduce it to the equivalent quantity of hydrometer proof spirit. But the "per cent. above or below proof" of Dycas is the quantity of water which may be added to or subtracted from the liquor, to reduce it to liquor of the strength of proof. Now, these quantities are not the same; for when alcohol and water are mixed, a molecular attraction or condensation takes place, which renders the volume of the mixture considerably less than the sum of the volumes of the liquids mixed; and this condensation may amount to more than three and a half per cent.

109. Although the above-described system of proofs has been for more than fifty years established by law for levying duties on foreign spirits imported into the United States, it does not appear to be in harmony with the mercantile system; and has therefore been rejected in commerce. In New York, a single proof has been by law adopted, and duties are laid on strengths shown directly by Southworth's hydrometer in per cent. above and below this proof. In Boston, a hydrometer has been brought forward by Messrs. Tucker and Dwelle, apparently copied from that of Sikes, but which is based upon proof spirit of "the American mercantile standard," which seems to be the first proof of the United States, or Holland proof of Europe. In Philadelphia, by law of the State of Pennsylvania, passed April 15, 1835, it is enacted, "that if the liquor shall be hydrometer proof, (by Dycas's hydrometer,) it shall be marked as liquor of the fourth proof; if five degrees below hydrometer proof, it shall be marked as liquor of the third proof; if the liquor shall be ten degrees below hydrometer proof, it shall be marked as of the second proof; if it shall be fifteen degrees below hydrometer proof, it shall be marked as of the first proof." In Baltimore, I am informed that, by act of the legislature of Maryland, the gaugers are required to mark on each cask its contents reduced to "first proof" spirit, (United States standard,) to certify the same to the vendor, and to give no other information. Hence it would seem that, with the exception of "first proof" spirit, the standards established by law are arbitrary, and that they might even be abolished, and a different and

simpler system adopted, without inconvenience in commerce, and with advantage in the revenue. Before recommending, however, any particular change in the existing regulations, it is, in my opinion, expedient to consult the views and wishes of merchants who are well informed upon these subjects, and who have imported large quantities of spirits from foreign countries.

*Experiments of comparison of several of the hydrometers used for spirits.*

110. The temperatures were observed by three different thermometers, one of the centigrade scale, made by Greiner, of Berlin; another by Bate, the hydrometer maker to the revenue of Great Britain; and a third by Fisher, of Philadelphia; the two last belonging to the hydrometers of Sikes and Dycas used in the experiments. To verify their zero points, the thermometers were placed at the same time in pure melting ice, and were found to be stationary at the following points: Greiner, at + 1° centigrade; Bate, at 34°.5 Fahrenheit; Fisher, at 33° Fahrenheit. The errors of the zero points are therefore, respectively, + 1° centigrade, 2°.5 Fahrenheit, and 1° Fahrenheit. Two sets of observations were then made, one for a constant temperature varying the strength, and another for variable temperatures and a constant degree of strength. The following are the observations, exactly as they were made.

111. The temperature being nearly constant, and the strength variable, descending:

| Thermometer. | | | Hydrometers. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Greiner. | Bate. | Fisher. | Gay Lussac —Collardeau. | G. Lussac.—Pixii. | Dycas.—Fisher. | Sikes.—Bate. | Beaume.—Greiner. | Beaume.—Pixii. | Beck. | Cartier. |
| ° C. | ° F. | ° F. | | | o | o | o | o | o | o |
| 22.7 | 72.8 | 72.7 | .... | .... | 246.9 | 29.2 | 33. | 30.1 | 2!.3 | 31. |
| 22.5 | 72.3 | 72.8 | 71. | 71.3 | 205. | 41.5 | 28.7 | 27. | .... | 26.8 |
| 22.3 | 72. | 72. | 67.25 | 67.3 | 186.2 | 46.6 | 27.7 | 25. | 15.6 | 25. |
| 22. | 71.7 | 71.5 | 64.1 | 64.6 | 173.5 | 50.58 | 25.2 | 24. | 14.3 | 23.7 |
| 22.6 | 72.5 | 72.5 | 59. | 59.5 | 150.9 | 57.9 | 23.1 | 22. | 12.3 | 21.7 |
| 22.5 | 72.3 | 72.2 | 55.2 | 55.5 | 136.5 | 61.1 | 22. | 20.5 | 11.2 | 20.3 |
| 22.5 | 72.3 | 72.5 | 49.5 | (*) | 115.6 | 67.2 | 20.2 | 19 | 9.2 | 18.25 |
| 23. | 73.7 | 73.7 | 42.5 | (*) | 93.3 | 73.6 | 18.3 | 17.25 | 7.2 | 15.25 |
| 23. | 73.5 | 73.5 | 38.6 | (*) | 81.8 | 77.1 | 17. | 16.2 | 6.2 | |

* So inclined, owing to want of symmetry of form, as to render reading impracticable.

These observations were made under the most favorable circumstances; for both the temperature and degree of strength were in a statical condition at the time of reading. In the following series,

however, the temperature was in a dynamical condition, with but three exceptions.

112. The manner in which the influence of temperature was observed in these experiments was by enclosing the bell-glass, (a large one,) containing the alcoholic solution, in another much larger one, and then filling the intervening space first with hot water, and subsequently with melting ice. The temperature and the indications of the different hydrometers were read off before adding the hot water or the ice, when the whole was in a statical condition, and again after the mixture and the apparatus had acquired the temperature of the room. When the temperature of the liquor was in a dynamical state, it was impracticable to read all the hydrometers before the thermometer indicated a different degree; it was therefore not attempted; and greater accuracy was attained by reading several at intermediate tempesatures. No observations were made until sufficient time had elapsed to allow an equilibrium to take place of the ascending and descending currents of different density, except in so far as they might be produced by the temperature of the room and of surrounding bodies.

| Thermometers. | | | Hydrometers. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Greiner. | Bate. | Fisher. | Gay Lussac.—Collardeau. | G. Lussac.—Pixii. | G. Lussac.—Pixii. | Dycas.—Fisher. | Sikos.—Bate. | Beaumé.—Greiner. | Beaumé.—Pixii. | Beaumé.—Heintz. |
| 16°.8 C. | ° F. | 66°F. | 87°.3 | 87°.3 | 86°.5 | 292°.3 | 16°.2 | 37°.3 | 33°.8 | 33°.4 |
| .... | .... | 84. | 90.5 | 90.5 | .... | 312. | 10.7 | .... | .... | .... |
| 27.8 | 81.7 | 81.7 | 89.8 | 89.8 | .... | 307.6 | 12. | 39. | .... | .... |
| .... | 81. | .... | .... | .... | .... | ..... | .... | .... | 35. | 34.3 |
| 26. | 80. | 80. | 89.4 | 89.4 | .... | 305. | 12.6 | .... | .... | .... |
| .... | 76.7 | 76.6 | 88.8 | 89. | 88.2 | 302.4 | 13.3 | 38.3 | 34.8 | 34. |
| .... | 76. | 76. | 88.5 | 88.8 | .... | 303.3 | 13.6 | 38. | 34.5 | 34. |
| .... | 75. | 75. | 88.6 | 88.6 | .... | 301. | 13.8 | 38. | .... | .... |
| 19.7 | 67.5 | 68. | 87.2 | 87.1 | 86.6 | 291. | 16.8 | 37.25 | 33.6 | 33. |
| 1. | (*) | 33. | 82. | 82.2 | 81.5 | 262.8 | 24.9 | 34.3 | 31.3 | 30.5 |
| .... | .... | 38. | 83. | 83. | .... | 272. | 22.7 | 35. | .... | .... |
| 5. | .... | 40. | 83.4 | 83.5 | .... | 273.5 | 22.1 | 35.2 | .... | .... |
| .... | .... | 43. | 83.9 | 84. | 83.5 | 275.7 | 21.4 | 35.4 | 32.5 | .... |
| 8. | .... | 46. | 84.1 | 84.3 | .... | 277.3 | 20.9 | 35.5 | 33. | .... |
| 11. | 50. | 50.2 | 85. | 85.2 | .... | 282.1 | 19.2 | 36. | .... | .... |
| .... | 59. | 59. | 85.7 | 86. | .... | 284.5 | 18.7 | 36.2 | .... | .... |
| 17. | 60. | 60. | 86. | 86.2 | 85.3 | 285.5 | 18.2 | 36.3 | .... | .... |
| 17. | 60.7 | 60.5 | 86.1 | .... | .... | ..... | .... | .... | 33.5 | 32.8 |
| 20. | 68. | 67.5 | 87. | 87.1 | 86.5 | 291.2 | 16.6 | 37.2 | 33.9 | 33.9 |

* Scale warped so that it could not be used.

I have felt at a loss to account for the close accordance in these experiments of the indications of temperature given, respectively, by the thermometers of Bate and Fisher; and I feel inclined to suspect the observation of the zero point of Bate's thermometer, as stated in article 110, of inaccuracy. But I was not at the time aware of any error, if it occurred, as I now suppose it probably did. The centigrade thermometer of Greiner was a laboratory thermometer, not of sufficient sensibility to be read accurately within a quarter of a degree.

The alcoholometer of M. Gay Lussac, made by M. Collardeau, who is the hydrometer maker to the French government, appears to be one which was manufactured several years ago; and it was procured, I believe, for the Treasury Department, by the late Mr. Hassler. I have recently imported another instrument of the same kind, and by the same maker, and I find them to agree perfectly in their indications. The two alcoholometers of Gay Lussac, which I have recorded as of the make of M. Pixii, are of very inferior workmanship; they are not marked with any name, and I attribute them to M. Pixii solely because I was told by the importer that they are of his manufacture, but I may not have been correctly informed. The pèse-esprit of Beaumé, which I have set down as of the manufacture of M. Pixii, bears his name upon its scale.

113. To render the preceding comparative observations more distinct; I have reduced the indications of the hydrometers of Sikes, Dycas, and Gay Lussac, of the first series of experiments, to their equivalent per cent. by volume of absolute alcohol. Their discrepancy is thus rendered manifest.

| Gay Lussac. | Dycas. | Sikes. | Gay Lussac. | Dycas. | Sikes. |
|---|---|---|---|---|---|
| .... | 75.9 | 77.7 | 52.5 | 53. | 53. |
| 68.6 | 68.2 | 69. | 46.7 | 47.4 | 47. |
| 64.8 | 64.5 | 65.5 | 39.3 | 39.9 | 39. |
| 61.7 | 61.8 | 62.9 | 35.3 | 36.1 | 35 |
| 56.3 | 56.5 | 56. | | | |

I do not think there can be any doubt which of these instruments is the most exact, for the high and well-earned reputation of M. Gay Lussac at once claims for his researches our credit, apart from the simplicity of his hydrometer, and its consequent perfection.

114. From the second series of observations, and the tables of M. Gay Lussac for mixing liquors, I derive the data for the following comparison of the reduced indications of the hydrometer of Gay Lussac and Dycas:

| Gay Lussac. | | Dycas. | Gay Lussac. | | Dycas. | Gay Lussac. | | Dycas. |
|---|---|---|---|---|---|---|---|---|
| Per cent. by vol. | Over proof. | Over proof. | Per cent. by vol. | Over proof. | Over proof. | Per cent. by vol. | Over proof. | Over proof. |
| 86.16 | 54.5 | 50.6 | 86.16 | 54.5 | 50.7 | 86.06 | 54.3 | 51.5 |
| 86.76 | 55.6 | 51.5 | 85.81 | 53.9 | 49.7 | 86.4 | 54.9 | 51.8 |
| 86.4 | 54.9 | 51. | 86.05 | 54.3 | 50.6 | 85.75 | 53.8 | 50.8 |
| 86.2 | 54.6 | 50.7 | 86.2 | 54.6 | 51.9 | 85.85 | 54. | 50.3 |
| 86.25 | 54.6 | 50.7 | 86.35 | 54.9 | 51.7 | 85.9 | 54.2 | 50. |
| 86.15 | 54.5 | 51.3 | 86.35 | 54.9 | 51.7 | 85.9 | 54.2 | |

It appears, therefore, that there is a discrepancy of these instruments for spirits of the strength used in the experiments of nearly 4 per cent. An equation for penetration or condensation would cause these "over proofs" to accord very closely, but such an equation is not admissible for Dycas's hydrometer.

115. In conclusion, I would add, that it seems to be desirable that a series of accurate chemical analyses should be made, with the view of determining the nature and quantities of vegetable extractive matter contained in the various distilled spirits of commerce, and the consequent influence exerted upon the density. The use of hydrometers assumes this influence to be inappreciable; but I do not find published experiments upon which I can rely, though I doubt not such have been made by M. Gay Lussac and others.

Respectfully submitted, by

RICHARD S. McCULLOH.

Professor A. D. Bache.

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A.

Philadelphia, *August* 1, 1843.

Sir: Agreeably to your request, made known to us through Dr. D. B. McGinley and Mr. T. Stewart, we have undertaken the analysis of the specimens of molasses sent to us by them, and have endeavored to devise a practical method of determining the quantities of crystallizable sugar contained in them. About to close our laboratory until the 1st of September, we offer you at present our results in regard to the specimens handed to us. But, in order to understand the difficulties attending the contrivance of a method for ascertaining the quantity of crystallizable sugar present, permit us to make the few following remarks:

Sirups and molasses contain at least two varieties of sugar, which we will distinguish by the names of crystallizable and uncrystalizable, or molasses sugar, (sometimes termed caramel.) The first may be obtained from its solution in solid form, either as an aggre

gation of small crystals, as in loaf sugar; or in large crystals, as in sugar candy; or more impure, as small colored and loose crystalline grains, constituting the different varieties of brown sugar. (All brown sugars may be refined into loaf sugar, if it otherwise pays the trouble in an economical point of view.) Molasses sugar, on the other hand, is soluble in water, in all proportions, and imparts therefore a richer sweetness to it; nor can it be obtained in a solid state, excepting by evaporating its water at a higher temperature, when it forms a fused mass, which solidifies, on cooling, into a brown, hard, and glassy mass; it again softens in the air by attracting moisture. These two varieties of sugar are ascertained to be entirely distinct in their composition and behavior to tests. Very slight chemical causes will convert the former into the latter, such as heat, acids, alkalies, albuminous and other nitrogenized substances, such as are found in vegetable juices; while the latter has never been restored to the former or crystallized state. Now, where the two are mingled together, as in most molasses and sirups, the viscid nature of the uncrystallizable sugar impedes, the separation of the other in a crystalline state; the presence of foreign matter, such as sacchulmine, gum, extractive matter, etc., forms an increased hinderance to the separation of crystallized sugar, its particles being prevented from uniting. In attempting the removal of these ingredients by chemical means, the reagents are very apt to convert the crystallizable sugar into molasses sugar —thus defeating the object in their separation. You will hence perceive the difficulties of contriving a practical process for the quantitative estimation of crystallizable sugar in molasses and sirups, which has not yet fully succeeded, notwithstanding the valuable prizes offered by governments and scientific bodies to effect this object.

It is also evident, from the preceding remarks, that their value, for the purpose of extracting crystallizable sugar from them, depends not only on the actual amount of the latter in them, but also inversely on the amount of foreign substances; while, on the other hand, molasses, as such, improve in quality by the extraction of the crystallizable sugar, which, by separating, impair their transparency, while the purification which they undergo for its separation imparts to them a richer color and taste.

We subjoin the following table, as exhibiting the results of our experiments:

| | New Orleans molasses. | Porto Rico molasses. | New Orleans molasses. | Porto Rico molasses. | Porto Rico molasses. | Porto Rico molasses. | Arecibo (P. R.) molasses. | Matanzas molasses. | Matanzas sirup. | Matanzas molasses. | St. Croix molasses. | Trinidad de Cuba molasses. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. | No. 6. | No. 10. | No. 13. | No. 15. | No. 19. | No. 20. | No. 21. |
| Specific gravity | 1.361 | 1.348 | 1.384 | 1.375 | 1.369 | 1.321 | 1.376 | 1.371 | 1.297 | 1.361 | 1.362 | 1.365 |
| Weight of one gallon in avoirdupois pounds | 11.34 | 11.23 | 11.53 | 11.48 | 11.41 | 11.01 | 11.47 | 11.42 | 10.82 | 11.34 | 11.35 | 11.37 |
| Extractive and other foreign matter | 4.60 | 4.42 | 3.33 | 3.87 | 2.26 | 2.12 | 4.38 | 3.70 | 2.14 | 4.55 | 3.56 | 4.12 |
| Crystallizable sugar | 31.45 | ..... | 27.13 | ..... | 39.27 | 40.81 | 24.72 | 27.94 | 43.65 | ..... | 33.4 | 32.27 |
| Quality of sugar expressed in numbers from lowest up | 3 | ..... | 1 | ..... | 6¼ | 7 | 5¼ | 3¾ | 5 | ..... | 3 | 2 |

In regard to the first horizontal column, it may be remarked, that in those specimens where sugar had settled at the bottom, it was carefully stirred up with the molasses, before taking portions either for ascertaining the specific gravity, or for determining the amount of crystallizable sugar, &c. The specific gravity of the supernatant molasses would of course be somewhat lower. The second horizontal column is calculated from the first, and gives the true average weight of a gallon of the whole hogshead. Columns 3 and 4 give the comparative amount of extractive and other foreign matter, and of crystallizable sugar, in 100 parts of the molasses. These numbers must not be considered as determined with such scientific accuracy as can be obtained in other experiments, but still to be near enough to the truth to afford a good comparison, for practical purposes, of their content of crystallizable sugar. The last horizontal column expresses the apparent purity of the sugar, as we obtained it in our experiments from the different specimens.

Specimens Nos. 2, 3, 13, and 15, exhibited no appearance of any deposition of sugar in them. In No. 21 there is a slight deposition, and also a small one in Nos. 1, 10, 20, and 19, while the deposition in Nos. 4 and 5 is more considerable, and quite large in No. 6.

The greater or less specific gravity depends on the quantity of uncrystallizable sugar, and foreign matter, both of which are more soluble than crystallizable sugar, and therefore increase as the molasses are concentrated. The more of the molasses sugar they possess, the higher is therefore their specific gravity, (column 1;) the greater the amount of foreign matter, (column 3;) and the smaller the amount of crystallizable sugar, (column 4;) and in the same proportion is the latter more difficult to separate, and of inferior quality, (column 5).

We have been informed, from respectable sources, that the manufacture of inferior sugars from West India molasses has been carried on formerly when brown sugar sold at a high price. The amount obtained was from 30 to 35 per cent, but it was only from such molasses as had not been left long enough to deposite all its sugar, or from lack of strength in the sugar, or from carelessness, had carried away with it the finer particles of the sugar. The highest amount obtained was 35 per cent. while some of the New Orleans molasses were said to yield none. Another not unimportant object in this manufacture is the improvement of the molasses by the separation of the sugar and the purification which it undergoes for the purpose, as mentioned above.

We are indebted to Mr. T. Stewart and Dr. D. B. McGinley for the following information in regard to the amount of sugar obtained from molasses, as carried on at the present time in this city. Cienfuegos (Cuba) molasses, weighing $11\frac{3}{4}$ pounds to the gallon, yielded from 400 to 500 pounds of sugar to the hogshead. Supposing the hogshead to contain 125 gallons, this would be from 27 to 34 per cent. A single hogshead of the same cargo should have yielded as much as 600 pounds, or about 41 per cent. Other (Por-

to Rico) molasses yield 3 to 4 pounds to the gallon, or from 26 to 34 per cent. The better varieties of molasses sugar are worth 6 cents per pound. The molasses lose about one-third by this process.

Respectfully yours,

JAMES C. BOOTH,
MARTIN H. BOYE.

CALVIN BLYTHE, Esq.,
*Collector of the port of Philadelphia.*

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## TABLE I.

| Temp. 63½° Fahr. | | Temp. 63½° Fahr. | | Temp. 63½° Fahr. | | Temp. 63½° Fahr. | |
|---|---|---|---|---|---|---|---|
| Sugar per cent. | Density. | Sugar per cent. | Density. | Sugar per cent. | Density. | Sugar per cent. | Density. |
| 1 | 1.0035 | 18 | 1.0734 | 35 | 1.1538 | 52 | 1.2434 |
| 2 | 1.0070 | 19 | 1.0784 | 36 | 1.1582 | 53 | 1.2490 |
| 3 | 1.0106 | 20 | 1.0830 | 37 | 1.1631 | 54 | 1.2546 |
| 4 | 1.0143 | 21 | 1.0875 | 38 | 1.1681 | 55 | 1.2602 |
| 5 | 1.0179 | 22 | 1.0920 | 39 | 1.1731 | 56 | 1.2658 |
| 6 | 1.0215 | 23 | 1.0965 | 40 | 1.1781 | 57 | 1.2714 |
| 7 | 1.0254 | 24 | 1.1010 | 41 | 1.1832 | 58 | 1.2770 |
| 8 | 1.0291 | 25 | 1.1056 | 42 | 1.1883 | 59 | 1.2826 |
| 9 | 1.0328 | 26 | 1.1103 | 43 | 1.1935 | 60 | 1.2882 |
| 10 | 1.0367 | 27 | 1.1150 | 44 | 1.1989 | 61 | 1.2933 |
| 11 | 1.0410 | 28 | 1.1197 | 45 | 1.2043 | 62 | 1.2994 |
| 12 | 1.0456 | 29 | 1.1245 | 46 | 1.2098 | 63 | 1.3050 |
| 13 | 1.0504 | 30 | 1.1293 | 47 | 1.2153 | 64 | 1.3105 |
| 14 | 1.0552 | 31 | 1.1340 | 48 | 1.2209 | 65 | 1.3160 |
| 15 | 1.0600 | 32 | 1.1388 | 49 | 1.2265 | 66 | 1.3215 |
| 16 | 1.0647 | 33 | 1.1436 | 50 | 1.2322 | | |
| 17 | 1.0698 | 34 | 1.1484 | 51 | 1.2378 | | |

## TABLE II.

| Sugar, per cent. by weight. | Deg. (Beaumé) 59° Fahr.- | Specific gravity at 59° Fahr. | Sugar, by weight, in kilogrammes. (Kilog. = 2.205 pounds.) | Water, by weight, in kilogrammes. (Kilog. = 2.205 pounds.) | Volume in litres. (Litre = 0.2205 imp. gallons.) | Weight of sugar in 100 litr., or 22.05 gallons. |
|---|---|---|---|---|---|---|
| | | | | | | Kilog. |
| 3.2 | 1.75 | 1.015 | 100 | 2945 | 3000 | 3.33 |
| 3.3 | 2. | 1.018 | 100 | 2445 | 2500 | 4. |
| 4.8 | 2.50 | 1.022 | 100 | 1945 | 2000 | 5. |
| 6.4 | 3.50 | 1.030 | 100 | 1445 | 1500 | 6.66 |
| 9.5 | 5. | 1.045 | 100 | 945 | 1000 | 10. |
| 11.7 | 6.50 | 1.0559 | 100 | 750 | 805 | 12.42 |
| 13.3 | 7.50 | 1.0638 | 100 | 650 | 705 | 14.18 |
| 15.3 | 8.50 | 1.0744 | 100 | 550 | 605 | 16.5 |
| 18.1 | 10.15 | 1.0891 | 100 | 450 | 505 | 19.8 |
| 22.2 | 12.50 | 1.1111 | 100 | 350 | 405 | 24.6 |
| 28.5 | 16. | 1.1475 | 100 | 250 | 305 | 32.7 |
| 33.3 | 18.50 | 1.1707 | 100 | 200 | 256.25 | 39. |
| 35.7 | 19.50 | 1.1765 | 100 | 180 | 238 | 42. |
| 38.4 | 21. | 1.1872 | 100 | 160 | 219 | 45.66 |
| 41.6 | 22.50 | 1.2000 | 100 | 140 | 200 | 50. |
| 45.4 | 25. | 1.2222 | 100 | 120 | 180 | 55.5 |
| 50. | 27.25 | 1.2578 | 100 | 100 | 159 | 62.88 |
| 52.6 | 29. | 1.2666 | 100 | 90 | 150 | 66.66 |
| 55.5 | 30.50 | 1.2811 | 100 | 80 | 140.5 | 71.17 |
| 58.8 | 32. | 1.2979 | 100 | 70 | 131 | 76.35 |
| 62.5 | 33.75 | 1.3223 | 100 | 60 | 121 | 82.64 |
| 66.6 | 37. | 1.3453 | 100 | 50 | 111.5 | 89.68 |

## TABLE III.

| Per cent. of cane sugar in the unit of weight of the solution. | Density of the solution; that of distilled water being unity. | Arc of rotation described by the plane of polarization of the red ray, transmitted through a thickness of 160 millimetres. | Per cent. of cane sugar in the unit of weight of the solution. | Density of the solution; that of distilled water being unity. | Arc of rotation described by the plane of polarization of the red ray, transmitted through a thickness of 160 millimetres. |
|---|---|---|---|---|---|
| 1 | 1.004 | 0.688 | 10 | 1.040 | 9.196 |
| 2 | 1.008 | 1.783 | 11 | 1.045 | 10.153 |
| 3 | 1.012 | 2.684 | 12 | 1.049 | 11.128 |
| 4 | 1.016 | 3.593 | 13 | 1.053 | 12.104 |
| 5 | 1.020 | 4.509 | 14 | 1.057 | 13.087 |
| 6 | 1.024 | 5.432 | 15 | 1.062 | 14.079 |
| 7 | 1.028 | 6.363 | 25 | 1.105 | 24.413 |
| 8 | 1.032 | 7.300 | 50 | 1.231 | 54.450 |
| 9 | 1.036 | 8.244 | 65 | 1.311 | 75.394 |

## TABLE IV,

*Constructed by M. Francœur, showing the correspondence of the degrees of Beaumé's hydrometers with specific gravities at 54½° Fahrenheit.*

| Pèse-acide of Beaumé. | | | | | | Pèse-esprit of Beaumé. | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees. | Specific gravity. | Degrees. | Specific gravity. | Degrees. | Specific gravity. | Degrees. | Specific gravity. | Degrees. | Specific gravity. |
| 0 | 1.0000 | 26 | 1.2063 | 52 | 1.5200 | 10 | 1.0000 | 36 | 0.8488 |
| 1 | 1.0066 | 27 | 1.2160 | 53 | 1.5353 | 11 | 0.9932 | 37 | 0.8439 |
| 2 | 1.0133 | 28 | 1.2258 | 54 | 1.5510 | 12 | 0.9865 | 38 | 0.8391 |
| 3 | 1.0201 | 29 | 1.2358 | 55 | 1.5671 | 13 | 0.9799 | 39 | 0.8343 |
| 4 | 1.0270 | 30 | 1.2459 | 56 | 1.5833 | 14 | 0.9733 | 40 | 0.8295 |
| 5 | 1.0340 | 31 | 1.2562 | 57 | 1.6000 | 15 | 0.9669 | 41 | 0.8249 |
| 6 | 1.0411 | 32 | 1.2667 | 58 | 1.6170 | 16 | 0.9605 | 42 | 0.8202 |
| 7 | 1.0483 | 33 | 1.2773 | 59 | 1.6344 | 17 | 0.9542 | 43 | 0.8156 |
| 8 | 1.0556 | 34 | 1.2881 | 60 | 1.6522 | 18 | 0.9480 | 44 | 0.8111 |
| 9 | 1.0630 | 35 | 1.2992 | 61 | 1.6705 | 19 | 0.9420 | 45 | 0.8066 |
| 10 | 1.0704 | 36 | 1.3103 | 62 | 1.6889 | 20 | 0.9359 | 46 | 0.8022 |
| 11 | 1.0780 | 37 | 1.3217 | 63 | 1.7070 | 21 | 0.9300 | 47 | 0.7978 |
| 12 | 1.0857 | 38 | 1.3333 | 64 | 1.7273 | 22 | 0.9241 | 48 | 0.7935 |
| 13 | 1.0935 | 39 | 1.3451 | 65 | 1.7471 | 23 | 0.9183 | 49 | 0.7892 |
| 14 | 1.1014 | 40 | 1.3571 | 66 | 1.7674 | 24 | 0.9125 | 50 | 0.7849 |
| 15 | 1.1095 | 41 | 1.3694 | 67 | 1.7882 | 25 | 0.9068 | 51 | 0.7807 |
| 16 | 1.1176 | 42 | 1.3818 | 68 | 1.8095 | 26 | 0.9012 | 52 | 0.7766 |
| 17 | 1.1259 | 43 | 1.3945 | 69 | 1.8313 | 27 | 0.8957 | 53 | 0.7725 |
| 18 | 1.1343 | 44 | 1.4074 | 70 | 1.8537 | 28 | 0.8902 | 54 | 0.7684 |
| 19 | 1.1428 | 45 | 1.4206 | 71 | 1.8765 | 29 | 0.8848 | 55 | 0.7643 |
| 20 | 1.1515 | 46 | 1.4339 | 72 | 1.9000 | 30 | 0.8795 | 56 | 0.7604 |
| 21 | 1.1603 | 47 | 1.4476 | 73 | 1.9241 | 31 | 0.8742 | 57 | 0.7565 |
| 22 | 1.1692 | 48 | 1.4615 | 74 | 1.9487 | 32 | 0.8690 | 58 | 0.7526 |
| 23 | 1.1783 | 49 | 1.4758 | 75 | 1.9740 | 33 | 0.8639 | 59 | 0.7487 |
| 24 | 1.1875 | 50 | 1.4902 | 76 | 2.0000 | 34 | 0.8588 | 60 | 0.7449 |
| 25 | 1.1968 | 51 | 1.4951 | | | 35 | 0.8538 | 61 | 0.7411 |

## TABLE V,

*Showing the discordant results of different observers, obtained by experimental comparison of Beaumé's hydrometers with specific gravities at 54½° Fahrenheit.*

| Pèse-acide. | | | | Pèse-esprit. | | | | |
|---|---|---|---|---|---|---|---|---|
| Degrees. | Francœur. | Delezennes. | Gilpin. | Degrees. | Francœur. | Delezennes. | Gilpin. | Holland pharmacopœia. |
| 0 | 1.0000 | 1.0000 | 1.000 | 10 | 1.0000 | 1.0000 | 1.000 | 1.000 |
| 3 | 1.0201 | 1.0219 | 1.020 | 15 | 0.9669 | 0.9655 | 0.963 | 0.967 |
| 6 | 1.0411 | 1.0448 | 1.040 | 20 | 0.9359 | 0.9333 | 0.928 | 0.935 |
| 9 | 1.0630 | 1.0687 | 1.064 | 25 | 0.9068 | 0.9033 | 0.897 | 0.906 |
| 12 | 1.0857 | 1.0937 | 1.089 | 30 | 0.8795 | 0.8751 | 0.867 | 0.878 |
| 15 | 1.1095 | 1.1200 | 1.114 | 31 | 0.8742 | 0.8696 | 0.861 | 0.873 |
| 18 | 1.1343 | 1.1475 | 1.140 | 32 | 0.8690 | 0.8643 | 0.856 | 0.868 |
| 21 | 1.1603 | 1.1764 | 1.170 | 33 | 0.8639 | 0.8590 | 0.852 | 0.863 |
| 24 | 1.1875 | 1.2068 | 1.200 | 34 | 0.8588 | 0.8539 | 0.847 | 0.858 |
| 27 | 1.2160 | 1.2389 | 1.230 | 35 | 0.8539 | 0.8186 | 0.842 | 0.852 |
| 30 | 1.2459 | 1.2727 | 1.261 | 36 | 0.8488 | 0.8435 | 0.837 | 0.847 |
| 33 | 1.2773 | 1.3083 | 1.295 | 37 | 0.8439 | 0.8384 | 0.832 | 0.842 |
| 36 | 1.3103 | 1.3333 | 1.333 | 38 | 0.8391 | 0.8334 | 0.827 | 0.837 |
| 39 | 1.3451 | 1.3861 | 1.373 | 39 | 0.8343 | 0.8285 | 0.822 | 0.832 |
| 42 | 1.3818 | 1.4285 | 1.414 | 40 | 0.8295 | 0.8236 | 0.817 | 0.828 |
| 45 | 1.4206 | 1.4735 | 1.455 | 41 | 0.8249 | 0.8188 | 0.814 | 0.823 |
| 48 | 1.4615 | 1.5217 | 1.500 | 42 | 0.8202 | 0.8141 | 0.811 | 0.819 |
| 51 | 1.4951 | 1.5730 | 1.547 | 43 | 0.8156 | 0.8094 | 0.808 | 0.814 |
| 54 | 1.5510 | 1.6279 | 1.594 | 44 | 0.8111 | 0.8017 | 0.805 | 0.810 |
| 57 | 1.6000 | 1.6868 | 1.659 | 45 | 0.8066 | 0.8001 | 0.802 | 0.805 |
| 60 | 1.6522 | 1.7501 | 1.717 | 46 | 0.8022 | 0.7956 | 0.799 | 0.800 |
| 63 | 1.7070 | 1.8184 | 1.779 | 47 | 0.7978 | 0.7911 | 0.797 | 0.796 |
| 66 | 1.7674 | 1.8922 | 1.848 | 48 | 0.7935 | 0.7866 | 0.795 | 0.792 |
| 69 | 1.8313 | 1.9721 | 1.920 | 49 | 0.7892 | 0.7823 | 0.793 | 0.787 |
| 70 | 1.8537 | 2.0003 | | 50 | 0.7849 | 0.7779 | 0.791 | 0.782 |

## TABLE VI.

| Per cent. of alcohol by the alcoholometer. | G. Lussac's specific gravity at 15° C., according to Marozeau. | Tralles's specific gravity at 60° Fahr., according to Tralles. | Meissner's specific gravity at 14° R., according to Joss. | Per cent. of alcohol by the alcoholometer. | G. Lussac's specific gravity at 15° C., according to Marozeau. | Tralles's specific gravity at 60° Fahr., according to Tralles. | Meissner's specific gravity at 14° R., according to Joss. |
|---|---|---|---|---|---|---|---|
| 0 | 1.000 | 0.9991 | 1.000 | 55 | 0.926 | 0.9234 | 0.919 |
| 5 | 0.993 | 0.9919 | 0.993 | 60 | 0.915 | 0.9126 | 0.908 |
| 10 | 0.987 | 0.9857 | 0.986 | 65 | 0.904 | 0.9013 | 0.896 |
| 15 | 0.981 | 0.9802 | 0.980 | 70 | 0.891 | 0.8892 | 0.883 |
| 20 | 0.976 | 0.9751 | 0.976 | 75 | 0.879 | 0.8765 | 0.870 |
| 25 | 0.971 | 0.9700 | 0.970 | 80 | 0.865 | 0.8631 | 0.857 |
| 30 | 0.966 | 0.9646 | 0.964 | 85 | 0.851 | 0.8488 | 0.843 |
| 35 | 0.960 | 0.9583 | 0.958 | 90 | 0.835 | 0.8332 | 0.829 |
| 40 | 0.953 | 0.6510 | 0.949 | 95 | 0.818 | 0.8157 | 0.811 |
| 45 | 0.945 | 0.9427 | 0.940 | 100 | 0.795 | 0.7939 | 0.793 |
| 50 | 0.936 | 0.9335 | 0.930 | | | | |

PLATE I.

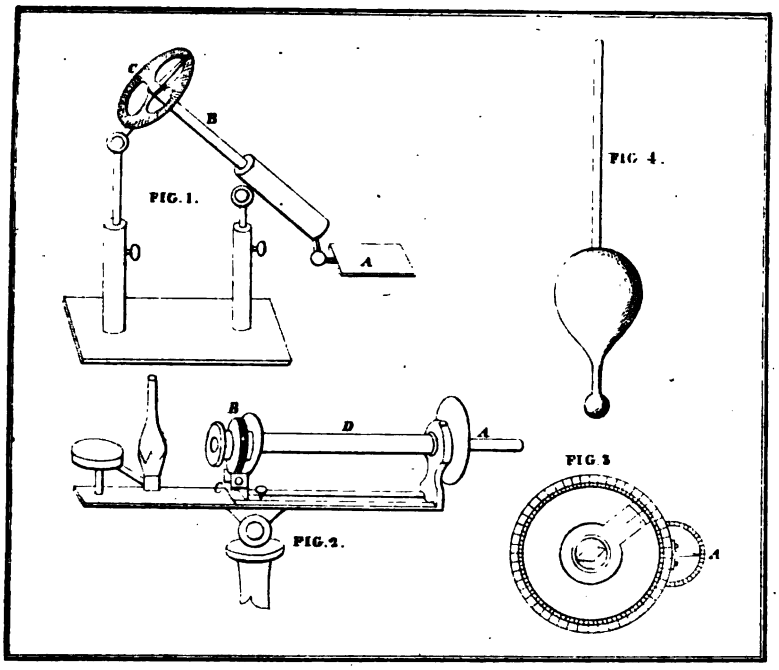
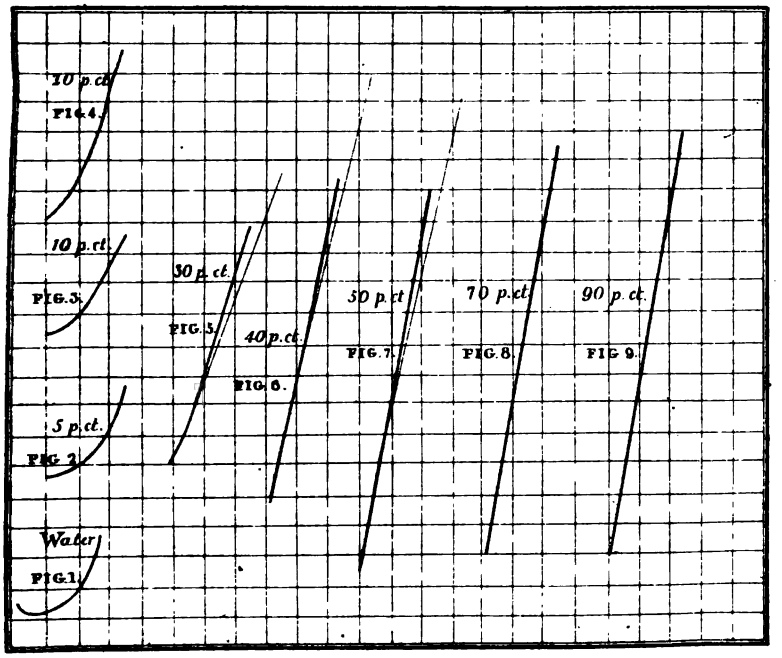



PLATE II.




tom-houses, contained in Senate document No. 12, 28th Congress,

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# REPORT

OF

# THE SECRETARY OF THE TREASURY,

IN COMPLIANCE WITH A RESOLUTION OF THE SENATE,

*elative to frauds in recent importations of sirups and molasses from the West India islands, and the measures necessary to be adopted to prevent their recurrence.*

August 3, 1846.
Read, and ordered to be printed.

Treasury Department, *July* 31, 1846.

Sir: In compliance with the resolution of the Senate, dated the 6th ultimo, instructing the Secretary of the Treasury "to report to the Senate such proofs as may be in his department as to the frauds reported to have been committed by recent importations from the West India islands into the port of New York, and other ports of the United States, of sirups as molasses, and to report such measures as may be necessary to guard against such frauds," I have e honor to submit the following enumerated papers from the files this department:

*First.* Report from Professor A. D. Bache, superintendent of ights and measures, &c., communicating a report addressed to him by Professor R. S. McCulloh, charged with researches in regard to sugars, sirups, and molasses, "on the chemical nature of substances imported into the United States under the name of molasses, with the view of defrauding the revenue," (marked A.)

*Second.* Reports from the several custom-houses at which importations of molasses appear, from the records of the department, to have been recently made, (numbered 1 to 19.)

*Third.* Communication from Messrs. Holt & Owen, importers of m lasses at New York, with certificate of dealers in the article, (numbered 20.)

It will be perceived, by the statements of the officers of the customs, that no case of fraud is reported as having occurred at either of the ports. A similar investigation having been instituted under the direction of Secretary Spencer, in May, 1843, the same result appears to have taken place, as shown by the reports from the custom-houses, contained in Senate document No. 12, 28th Congress,

2d session, to which the Senate is respectfully referred, as connected with this subject.

From the reports and accompanying documents now presented by the collector of New York, (Nos. 8, 9,) to which port the particular attention of the department was called by representations made by Mr. W. F. Wilkins, and the certificate of dealers in molasses, submitted by Messrs. Holt & Owen, (No. 20,) it will be observed that, while the officers of the customs and persons in trade concur in the opinion that the importations, in regard to which the special inquiry and examination were directed, were generally recognized and known in trade as molasses, the chemical analyses of Dr. Chilton and Dr. Thomas show that proportions as high as 58.25 per cent. of crystallizable or cane sugar were contained in some specimens of the articles so recognized in trade. In regard to these importations, Dr. Chilton states that in his analyses, during the last three or four years past, of various samples of molasses which had come to the port of New York from Cuba and other ports of the West Indies, he almost uniformly found them to contain from 65 to 75 per cent. of pure saccharine matter, although not all in a crystallizable state; and that the articles of Nuevitas molasses, the subject of the recent special examination, were found to be nearly the same as those he had previously analyzed.

The report of Professor McCulloh, now submitted, (A,) will be found to contain much to illustrate the subject. It is the second of a series of reports by Mr. McCulloh; the first presenting much valuable information, being contained in Senate document No. 165, 28th Congress, 2d session, and the third and final report being now in course of preparation. Until the completion of the views on this important subject to be offered to the department, it is not deemed advisable to submit any suggestion as to further legislation. From the close likeness of sirop de batterie to molasses of a good quality, as shown in the reports submitted, the former, in some instances, and to a small extent, may have been passed for the latter article. Under the increased vigilance of the custom-house officers now exercised, it is not likely that cases of a similar nature can again occur while the present tariff is in force; and the new tariff act, which will go into operation on the 1st of December next, by placing sirups and molasses under the same rate of duty, will, it is conceived, effectually remove any incentive to attempts at fraud or evasion of the legal duty on the articles in question.

All which is respectfully submitted.

R. J. WALKER,
*Secretary of the Treasury.*

Hon. GEORGE M. DALLAS,
*Vice President of the United States,*
*and President of the Senate.*

A.

OFFICE OF WEIGHTS AND MEASURES,
*July* 28, 1846.

SIR: I have the honor to transmit a report from Professor Richard S. McCulloh, charged by the department with researches in regard to sugars, sirups, &c., furnishing information upon the subject referred to in the resolution of the Senate of June 26th, in relation to the importation of sirups as molasses.

Very respectfully, yours,

A. D. BACHE,
*Supt. Weights, Measures, and Balances.*

Hon. ROBERT J. WALKER,
*Secretary of the Treasury.*

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PHILADELPHIA, *July* 20, 1846.

SIR: In reply to your letter of the 16th instant, requesting me to furnish whatever information I may have obtained in relation to the chemical nature of substances imported into the United States under the name of molasses, and with the view of defrauding the revenue, I respectfully submit the following report:

It has been alleged, as you are aware, that large quantities of sirup, composed of sugar dissolved in water, or of concentrated cane juice from which sugar has not been manufactured, are imported into the United States under the name of molasses; also, that these sirups are afterwards evaporated, and the sugar thus obtained either sold as muscovado, or refined, and sometimes even exported with allowance of drawback. And in this manner, it is supposed, extensive frauds are perpetrated on the revenue.

By reference to Senate Document No. 12, 2d session 28th Congress, it will be seen that the Hon. J. C. Spencer, then Secretary of the Treasury, by a circular, dated May 12, 1843, called the particular attention of the collectors of the principal ports to this subject, and directed them to cause examinations and analyses to be made to detect any frauds that might be committed. By the same document it also appears that this duty was fully and faithfully discharged by the revenue officers, and that much valuable information was in consequence obtained, all of which is given in detail in the document above cited.

Statements had been made, by persons supposed to be practically familiar with such subjects, that sirup of sugar, or concentrated cane juice, would be found to be heavier than molasses; and, therefore, that if the duty on molasses were levied per pound instead of by gallon, such frauds as the abovementioned would be rendered impracticable. In consequence of these statements, the duty of four and a half mills per pound was laid on molasses by the tariff act of 1842, instead of a duty levied per gallon, as before.

Not the least valuable result arrived at by the investigations

which were made in obedience to the abovementioned circular of the Secretary of the Treasury was the knowledge that the above statements, which caused a change in the mode of levying duty on molasses, had been made in ignorance and error; for the specimens of molasses which were examined were found to be specifically heavier than those of sirup, with which they were compared. And, also, it was observed that of any two varieties of molasses, that containing the larger proportion of crystallizable sugar had usually the least specific gravity.

But though the inquiries instituted by the Secretary of the Treasury led to such important facts as I have just mentioned, they failed to expose any frauds, and seemed to render the existence of fraudulent importations of sirup highly improbable. The large importations and seizures of sirup at New Orleans, in 1831, having aroused the vigilance of the officers of the revenue, and caused suitable legislation by Congress, it is most unlikely that any extensive frauds had been even attempted.

But the Treasury Department, not content merely with the limited examinations it had caused to be made, by a circular addressed August 12, 1845, by the First Comptroller, to the collectors of the ports of New York, Philadelphia, Boston, and Baltimore, directed them to have specimens taken of every lot or cargo of molasses which should arrive from any foreign port within sixty days after the receipt of the circular, and to send those specimens to me in Philadelphia for chemical analysis.

In making these and other scientific researches, I have, as you are aware, been assisted by J. B. Reynolds, esq., a young chemist of great ability, and whose analyses are entitled to entire confidence, both by reason of his careful manipulations and the experience he has acquired in optical analysis. And to him was intrusted their uninterrupted prosecution while I was absent, during the winter, in Louisiana and in Cuba, to which places I went, in compliance with your instructions, to make chemical analyses of cane juice and other substances, and to obtain such information as might be valuable either in the administration of the revenue laws, or in rendering better understood the processes employed in the manufacture of cane sugar. I hope shortly to present to you a full and final report of the investigations with which we have been charged; some analyses are still to be made, and I have not yet had sufficient time, since my return, to give a detailed account of the work performed. In the present partial report, I shall therefore set forth only those facts which relate, directly or indirectly, to the nature of the substances imported into the United States as molasses, and defer all other matters until I shall submit to you the abovementioned final report, which is already, in part, written, and will be soon finished.

The results of the analysis of sixty-five specimens of molasses and sirup are embodied in the following tables, Nos. I, II, III, and IV, together with such information, with respect to the place of production and importation, the quantity imported, the taste, the color, the specific weight, the angles of polarization, and the per

cent. of cane sugar contained, as will be sufficient to enable you to form a correct idea of each variety.

In table V, I give the results of the analysis of seven sediments, taken from casks in which some of the molasses analyzed was imported.

## TABLE I.

*Molasses from Cuba.*

| No. | Taste. | Color. | Direct angle of polarization. | Inverted angle of polarization. | Specific gravity. | Number of casks. | Where from. | Where imported. | Per cent. of cane sugar. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Acid | Dark | 21.9° | 5.7° | 1.342 | ... | Havana | Boston | 50.18 |
| 2 | Sweet | | 21.4 | 7.4 | 1.348 | ... | ...do | New York | 52.45 |
| 3 | Very acid | Dark | 22.3 | 6.4 | 1.360 | 43 | ...do | ...do | 52.22 |
| 4 | Dirty | ..do | 21.6 | 7.2 | 1.358 | ... | ...do | Philadelphia | 52.46 |
| 5 | Slightly acid | Very dark | 21.9 | 7.1 | 1.357 | ... | ...do | ...do | 52.65 |
| 6 | .....do | Dark | 23.7 | 7.5 | 1.348 | ... | ...do | ...do | 57.07 |
| 7 | .....do | ..do | 22.9 | 8.1 | 1.350 | ... | ...do | ...do | 56.13 |
| 8 | Sweet | ..do | 25.7 | 5.6 | 1.326 | ... | St. Jago | ...do | 52.89 |
| 9 | Very acid | ..do | 25.0 | 7.4 | 1.340 | ... | ...do | ...do | 59.12 |
| 10 | Acid | ..do | 25.0 | 8.0 | 1.334 | ... | ...do | ...do | 59.78 |
| 11 | ..do | Light | 20.9 | 6.3 | 1.350 | ... | ...do | Boston | 49.74 |
| 12 | ..do | Dark | 16.7 | 7.3 | 1.378 | ... | ...do | ...do | 44.05 |
| 13 | ..do | ..do | 24.1 | 5.5 | 1.455 | ... | Cienfuegos | Philadelphia | 50.38 |
| 14 | ..do | ..do | 22.8 | 7.8 | 1.377 | ... | ...do | Boston | 55.83 |
| 15 | Sweet | Light | 21.6 | 5.1 | 1.376 | ... | ...do | ...do | 48.98 |
| 16 | Vinous | Dark | 19.8 | 5.3 | 1.429 | ... | ...do | ...do | 48.75 |
| 17 | ..do | ..do | 23.9 | 7.2 | 1.367 | ... | ...do | ...do | 56.67 |
| 18 | ..do | Light | 23.8 | 7.2 | 1.369 | ... | ...do | ...do | 56.16 |
| 19 | Acid | Dark | 19.0 | 7.7 | 1.384 | 245 | Trinidad | New York | 48.77 |
| 20 | ..do | ..do | 20.9 | 6.7 | 1.362 | 245 | ...do | ...do | 50.71 |
| 21 | Vinous | ..do | 22.2 | 6.7 | 1.361 | ... | ...do | Philadelphia | 52.64 |
| 22 | Sweet | ..do | 20.1 | 5.9 | 1.360 | ... | ...do | Boston | 47.74 |
| 23 | Acid | Light | 21.2 | 4.7 | 1.349 | ... | ...do | ...do | 47.13 |
| 24 | ..do | Dark | 22.2 | 7.4 | 1.357 | ... | Matanzas | Philadelphia | 53.92 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 25 | ..do..... | ..do..... | 21.0 | 6.7 | 1.354 | ... | ...do..... | ...do..... | 50.64 |
| 26 | ..do..... | ..do..... | 20.0 | 6.0 | 1.357 | 49 | Cardonas ..... | New York ..... | 47.44 |
| 27 | Burnt ..... | ..do..... | 21.7 | 6.6 | 1.363 | ... | ...do..... | Boston..... | 51.86 |
| 28 | Vinous..... | ..do..... | 20.1 | 5.8 | 1.342 | ... | Sagua ..... | ...do..... | 47.69 |
| 29 | Acid ..... | ..do..... | 19.1 | 5.0 | 1.351 | ... | ...do..... | ...do..... | 44.25 |
| 30 | Bitter..... | ..do..... | 22.3 | 7.7 | 1.346 | ... | ...do..... | Baltimore..... | 54.82 |
| 31 | Vinous..... | Light..... | 22.5 | 7.2 | 1.354 | ... | San Juan de los Rem. | Boston..... | 53.80 |
| 32 | Acid ..... | Dark ..... | 22.4 | 7.2 | 1.369 | ... | Mariel..... | ...do..... | 54.49 |
| 33 | ..do..... | Light..... | 23.1 | 7.4 | 1.363 | 83 | Nuevitas ..... | New York ..... | 55.53 |
| 34 | Vinous..... | ..do..... | 27.3 | 5.6 | 1.336 | 64 | ...do..... | ...do..... | 59.60 |
| 35 | ..do..... | ..do..... | 24.6 | 7.6 | 1.337 | 7 | ...do..... | ...do..... | 59.00 |

## TABLE II.

*Porto Rico molasses.*

| No. | Taste. | Color. | Direct angle of polarization. | Inverted angle of polarization. | Specific gravity. | Number of casks. | Where from. | Where imported. | Per cent. of cane sugar. |
|---|---|---|---|---|---|---|---|---|---|
| 36 | Sweet..... | ..... | 21.4° | 7.4° | 1.365 | 163 | Porto Rico..... | New York..... | 52.45 |
| 37 | Acid ..... | Dark ..... | 21.2 | 7.2 | 1.369 | 44 | ...do..... | ....do..... | 51.51 |
| 38 | ..... | .... ..... | 22.7 | 7.6 | 1.377 | 29 | Ponce..... | ....do..... | 54.95 |
| 39 | Vinous..... | Light..... | 26.9 | 7.3 | 1.358 | ... | ...do..... | Philadelphia.... | 61.41 |
| 40 | Acid ..... | Dark ..... | 24.1 | 7.7 | 1.367 | ... | ...do..... | ....do..... | 57.84 |
| 41 | ..do..... | ..do..... | 25.3 | 7.8 | 1.371 | ... | ...do..... | Baltimore ..... | 60.00 |
| 42 | Vinous..... | Light..... | 19.5 | 6.8 | 1.376 | ... | ...do..... | ....do..... | 48.26 |
| 43 | ..... | ..... | 24.1 | 6.2 | 1.371 | 70 | Mayaguez ..... | New York ..... | 54.59 |
| 44 | Vinous..... | Light..... | 22.8 | 7.8 | 1.366 | 267 | ...do..... | ....do..... | 54.26 |
| 45 | Sweet ..... | ..do..... | 22.3 | 6.7 | 1.362 | 123 | ...do..... | ....do..... | 52.79 |
| 46 | Dirty..... | Dark ..... | 21.5 | 6.0 | 1.359 | 18 | ...do..... | Philadelphia .... | 49.79 |
| 47 | Acid ..... | Light..... | 23.7 | 7.2 | 1.348 | ... | ...do..... | Boston..... | 56.33 |
| 48 | ..do..... | ..do..... | 23.0 | 7.4 | 1.370 | ... | ...do..... | Baltimore ..... | 55.54 |
| 49 | ..do..... | Dark ..... | 25.8 | 7.1 | 1.354 | 161 | Guayama..... | New York ..... | 59.62 |
| 50 | Bitter..... | Light..... | 24.2 | 9.0 | 1.376 | ... | ...do..... | ....do..... | 60.23 |
| 51 | Acid ..... | ..... | 21.7 | 7.8 | 1.361 | 73 | ...do..... | ....do..... | 53.67 |
| 52 | ..do..... | ..... | 22.3 | 7.0 | 1.362 | 172 | ..do..... | ....do..... | 53.18 |

## TABLE III.

*Foreign molasses.*

| No. | Taste. | Color. | Direct angle of polarization. | Inverted angle of polarization. | Specific gravity. | Number of casks. | Where from. | Where imported. | Per cent. of cane sugar. |
|---|---|---|---|---|---|---|---|---|---|
| 53 | Acid ..... | Dark ..... | 20.9° | 6.6° | 1.337 | ... | Surinam ..... | Boston..... | 50.06 |
| 54 | ..do..... | Light..... | 21.9 | 8.6 | 1.376 | 190 | St. Croix..... | New York ..... | 55.58 |
| 55 | Sweet..... | ..do..... | 20.8 | 7.1 | 1.340 | ... | ...do..... | ...do..... | 51.04 |
| 56 | ..do..... | ..do..... | 24.7 | 7.1 | 1.378 | ... | St. Thomas .... | Boston..... | 57.86 |
| 57 | Vinous ..... | Dark ..... | 23.8 | 6.8 | 1.355 | ... | ...do..... | ...do..... | 57.29 |
| 58 | ..do..... | ..do..... | 21.6 | 6.9 | 1.357 | ... | St. John's..... | ...do..... | 51.88 |
| 59 | ..do..... | ..do..... | 21.0 | 6.2 | 1.353 | ... | ...do..... | ...do..... | 49.58 |

## TABLE IV.

*Sirups and domestic molasses.*

| No. | Taste. | Color. | Angle of polarization. | Inverted angle of polarization. | Specific gravity. | Per cent. of cane sugar. | Substance analyzed. |
|---|---|---|---|---|---|---|---|
| 60 | Acid | Dark | 22°.7 | 6°.2 | 1.352 | 52.50 | New Orleans molasses. |
| 61 | Burnt | ..do | 18.6 | 4.5 | 1.495 | 39.56 | Sugar-house molasses. |
| 62 | ..do | ..do | 18.8 | 4.8 | 1.400 | 43.00 | New Orleans sugar-house molasses. |
| 63 | Vinous | Light | 25.2 | 7.4 | 1.337 | 59.90 | Sirop de batterie. |
| 64 | Pure sweet | ..do | 27.7 | 7.3 | 1.446 | 59.05 | Lovering's sirup. |
| 65 | Very slightly burnt | ..do | 21.7 | 4.9 | 1.485 | 44.33 | Second quality sirup. |

## TABLE V.

*Sediments from molasses.*

| No. | Color. | Consistence. | Grain. | Per cent. of sugar. | No. of corresponding molasses. | Where from. |
|---|---|---|---|---|---|---|
| 1 | Dark .... | Granular ..... | Strong ... | 87.25 | 35 | Nuevitas. |
| 2 | Yellow... | Half granular. | Good .... | 71.56 | 34 | Nuevitas. |
| 3 | Dark .... | Half granular. | Good .... | 73.31 | 38 | Ponce, Porto Rico. |
| 4 | Dark .... | Granular ..... | Strong ... | 68.00 | 37 | Porto Rico. |
| 5 | Light.... | Granular..... | Strong ... | 77.62 | 44 | Mayaguez. |
| 6 | Light.... | Pasty..... | Fine ..... | 78.86 | 33 | Nuevitas. |
| 7 | Light.... | Half granular. | Good .... | 71.97 | 45 | Mayaguez. |

It appears from these results that density furnishes no indication of the proportion of crystallizable sugar contained in molasses, and that *sirop de batterie* is specifically lighter than most of the specimens of molasses analyzed; thus confirming by more numerous analyses the facts already set forth in Senate document No. 12, 2d session, 28th Congress.

These analyses also show that West India molasses usually contains about 52 per cent. of cane sugar, while *sirop de batterie*, and the sirup which drips from the loaves of refined sugar in refineries using Howard's vacuum pan and animal charcoal, contain about 60 per cent. New Orleans molasses was also found to contain 52 per cent.

The *sirop de batterie* analyzed was obtained by me in person from the boiling house on the Saratoga sugar estate near Matanzas, belonging to Drake, Brothers & Co., and it is a perfectly saturated solution, for it had deposited an abundant crop of crystals of sugar in the bottle which contained it. It is quite dark colored, of specific gravity 1.337, and of a sweet, slightly vinous taste. It is so much like the better varieties of molasses, that I am sure it would be mistaken for molasses by any except experienced judges. Herewith I send you a specimen of this article, together with a specimen of genuine Muscovado molasses, with which it may be compared in taste and appearance.

During my stay in Cuba I took pains to ascertain not only whether fraudulent importations of *sirop de batterie* from that island into the United States do, but whether they might readily, occur, and I am satisfied that *sirop de batterie* both can be, and is, *in small quantities*, imported as molasses, for, as above stated, they resemble each other most closely. In molasses there is almost always a slight burnt flavor, often, however, so delicate as to be barely perceptible, while *sirop de batterie* is destitute thereof. This might, however, be easily imparted if desired, by mixture with a small quantity of highly flavored molasses. I also learned

in Cuba, upon good authority, that much of the highly esteemed "Nuevitas molasses" is *sirop de batterie*, which, as a more beautiful and refined table article, readily commands a good price with grocers to a limited extent, the demand for it being small.

Of all the specimens of "molasses" submitted to me for analysis, there are but two which I consider to be sirup; and these were imported as "Nuevitas molasses" into the city of New York. Whether they paid duty as molasses, I have not been informed by the revenue officers who sent them to me. They are Nos. 34 and 35 of these analyses. Table V also shows that the sediment from No. 35 was composed of 87 per cent. of pure cane sugar; and when it is borne in mind that this sediment was a mass of solid particles intermixed with molasses or sirup, it follows that those solid particles were most probably sugar only, and of excellent quality. Of this variety there were but seven casks imported, a small quantity intended probably for table use only. I send herewith a specimen, which you may compare with the other specimens sent.

Much vagueness of opinion has heretofore existed as to what is the chemical nature of molasses. Whether it is a solution of degraded sugar rendered incapable of crystallization, and this, I believe, has been the most generally accepted theory; or whether it is itself some peculiar species of liquid sugar, or sirup rendered uncrystallizable by the presence of salts and other impurities. But the fact that, after performing a sea voyage and undergoing considerable alcoholic and even acetous fermentation, molasses contains generally 52 per cent. of crystallizable sugar, and yields by partial evaporation, a second crop of crystals of cane sugar, equal in weight to 35 per cent. of the molasses, establishes, I think, beyond question, the fact that molasses is only an impure solution of crystallizable sugar in water; the impurities being the saline and vegetable extractive matters existing in the cane juice. And if it be asked, what then is the chemical difference between molasses and *sirop de batterie*? I would reply, none. Yet *sirop de batterie* being the concentrated juice before granulation, and molasses the mother liquor after granulation, the impurities probably exist in larger proportion in the latter, for the reason that crystallization has served to purify as well as extract the sugar.

But though small quantities of *sirop de batterie* may have been fraudulently imported for table use, it is in the highest degree improbable that any extensive fraud should lately have been thus committed with the object of extracting sugar from such sirups; for genuine molasses, as shown by these analyses, contains 52 per cent. of cane sugar, while *sirop de batterie* contains, when saturated, 60 per cent. only; and the former sells at much lower prices. It is not, therefore, the interest of persons engaged in manufacturing sugar from molassses to buy sirup, from which they can extract but little more sugar than they can and do from molasses. Besides, it is more profitable and desirable to the planter of Cuba to extract and sell his sugar than to work his crop up into *sirop de batterie*, for the reason that Cuba sugars, being of a dry, firm grain, drain very little, and are therefore always sold readily and at good

prices, while *sirop de batterie* is a very perishable article, cannot be kept without fermentation, and is consequently but little in demand.

That under the existing tariff, which levies on raw sugar the duty of two and a half cents per pound, and on molasses a duty equivalent to about five cents per gallon, considerable quantities of molasses should have been evaporated, is certainly not surprising; for it has long been known to the sugar refiners that molasses thus yields about 35 per cent. of sugar. Hence from each gallon three and a half pounds may be obtained, on which the duty of five cents would have been paid, instead of eight and three quarter cents, the duty payable on three and a half pounds if imported as sugar.

The fact that molasses may be thus profitably evaporated, seems, until lately, to have been but little understood by the planters. Accustomed to regard it as a refuse article, containing no sugar of which the grain was not destroyed by the fire, they seem not to have thought it worth while to re-boil it. During the past year, however, the molasses on the Lizardi plantation in Louisiana is said to have yielded, by re-boiling, 40 per cent. of excellent sugar; and other planters have devoted attention to this subject. I have also seen on an estate near Guines, in Cuba, using vacuum pans, the entire crop manufactured into but two qualities of the very best sugar, *blanco primera* and *quebrado florete*, the latter being obtained exclusively from molasses.

At present, there are known to me three refineries in New York, two in Philadelphia, one in Portland, Maine, and one in Baltimore, which make it their business to evaporate molasses. Others may exist of which I have not heard. Of the amount of their operations I have no knowledge. But from my acquaintance with the extent of business and scale of magnitude of other refineries, and from those of the abovementioned establishments which I have visited, I should suppose them capable of producing 5,000 hogsheads of 1,000lbs.; in all, say 35,000 hogsheads of good brown sugar. Yet this estimate may be either greatly below or above their actual working. As hearsay only, I give the statement which was made to me by a grocer of New York, that the three refineries there evaporate 1,000 hogsheads of molasses per week, which would amount to the manufacture of about 25,000 hogsheads of sugar per annum. This I should, however, deem very improbable. But even estimating the whole amount of sugar thus manufactured in the United States at 35,000 hogsheads, it is evident that this branch of industry has acquired a magnitude and an importance which the Louisiana planter may well regard with attention, if not with some anxiety. For the Louisiana crop being only 200,000 hogsheads, it follows that there is produced and sold in competition therewith, in our home markets, a quantity of molasses sugar, or "clarified sugar," as it is called by the grocers, exceeding one-sixth of that crop.

Whether or not this business of making sugar from molasses should be fostered or checked by legislation, is a matter to be left

to those to decide to whom this and other questions of interest and policy are by the people intrusted. But it can only be arrested by levying on molasses a higher relative duty than it is now subject to in comparison with the duty on raw sugar.

It has been reported that there exists near Matanzas, on the river Uremi, a mysterious establishment, said to be used for converting sugars into sirup. The only foundation of this I suppose to be the fact, that there is a large sugar refinery so situated. I have been through it, and can bear witness to its being simply a sugar refinery, employing Howard's vacuum pans, bone black, and the usual accompanying machinery and fixtures. It formerly belonged to a company, but is now the property of an intelligent and enterprising gentleman, Mr. Adams, who has long conducted it. This also is, I believe, the only sugar refinery at present in the island of Cuba. Formerly, however, and in connexion with the importations of sirup in 1831, at New Orleans, Mr. Goodale, then and now a refiner of that city, caused to be built at Matanzas, as I have been told by himself and by persons residing near Matanzas, a house furnished with a train of pans for dissolving sugar in water. The sirup thus formed was the article he imported, and which was seized by the collector of New Orleans. Mr. Goodale had thus expended several thousand dollars, believing that he could, under the then existing laws, introduce sirup with profit and without liability to seizure. But the loss he sustained, in consequence of the seizures of his sirup, the costs of suits in which he became involved with the government, and the sacrifice of property he was obliged to make, effectually put an end to his operations. Whether the building used by Mr. Goodale for such purposes was on the river Uremi, or where it was in Matanzas, I know not; but perhaps it is the mysterious building to which the abovementioned report has reference.

The method employed for these analyses of molasses, sirups, sediments, &c., is that by means of circular polarization, which I have fully described and explained in a former report, published in Senate document No. 165, 2d session, 28th Congress, to which I beg leave to refer. This method I believe to be open to no objection. Some chemists of but little experience in the manipulations it requires, have supposed it to require longer time than analyses generally do. But I have found it practicable to make readily four analyses in twenty-four hours, which is a larger number than can generally be made by the usual manipulations of filtration, precipitation, et cetera. Besides, optical analysis has the advantage of employing a characteristic property of cane sugar without first subjecting it to the action of heat or of chemical reagents, which would convert a part of the sugar into substances of a different nature.

The manipulations and calculations were substantially identical with those given and fully set forth in my former report. It was, however, found that, in decolorizing the solutions, a slight quantity of subacetate of lead is, in some cases, very useful; and as it has no effect upon the cane sugar contained, I did not hesitate in a

few instances to employ it. The acid for inversion was added by measure in a graduated tube, and not as formerly by weight, the volume thereof being thus determined with sufficient exactness. The formulas were the same, but some simplifications were introduced in the calculations with economy both of time and labor. This was done by rendering constant the quantities employed; variations thus occur only by reason of specific differences in the specimens subjected to annalysis.

I am, very respectfuly, your obedient servant,

RICHARD S. McCULLOH.

To Professor A. D. Bache,
*Superintendent of Weights and Measures, &c.*

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No. 1.

Collr's Off., Dist. of Portland and Falmouth,
*Portland, June* 30, 1846.

Sir: I have the honor to acknowledge the receipt of your letter of the 27th instant, requiring me to report whether frauds have been practised or attempted at this port of importing sirups as molasses, and to give my views of the measures necessary to prevent a recurrence of such frauds.

No such frauds have ever been practised or attempted in this district since I have had charge of this office. If such frauds are practised any where, which I much doubt, they are committed with the knowledge and consent of the gauger, for the appearance of these sirups, as I am informed by ship-masters, is as different from molasses as is that of honey.

Let there be a forfeiture of vessel and cargo for all such attempts, and, if the gaugers do their duty, they will cease.

I have the honor to be, sir, with great respect, your obedient servant,

JOHN ANDERSON, *Collector.*

Hon. Robert J. Walker,
*Secretary of the Treasury, Washington.*

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No. 2.

Collector's Office, *Boston, June* 30, 1846.

Dear Sir: Your communication of the 27th instant, covering a resolution of the Senate of the day before, was received this morning. I immediately called on the surveyor of this port for a report in answer to your inquiry, a copy of which I sent him. I now have the pleasure to enclose his report.

I will also add that I have made inquiries of other officers in this department, and am fully satisfied of the entire correctness of

his statement. Indeed, I learn that but a single instance of the importation of sirup has been made in this port for two or three years past. And all the officers fully agree in the most entire conviction that no fraud of the kind referred to has been practised in this district.

I am, very respectfully, your obedient servant,

MARCUS MORTON, *Collector.*

Hon. R. J. Walker,
*Secretary of the Treasury, Washington, D. C.*

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Surveyor's Office, *June* 30, 1846.

Dear Sir: In answer to your letter of this date relative to frauds having been committed upon the revenue in New York and other ports, by importing sirups under the name of molasses, I can only say that I am very certain that nothing of the kind has taken place here. I have often called the attention of the gaugers to this subject, and they assure me that there has never been a fraud or an attempt at one in that article.

Yours, very respectfully,

J. McNIEL, *Surveyor.*

To the Collector, *Port of Boston.*

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No. 3.

Collector's Office, Custom-house,
*Salem, Mass., July* 2, 1846,

Sir: In answer to your communication of 27th ultimo respecting importations of sirups as molasses, I have to state that I am not aware of anything of the kind having taken place at this port.

Nearly all the molasses imported here is from Cayenne, French Guiana, although occasionally a cargo arrives from the West Indies. The greater part of this is for distilling, and the balance for retailing. I do not think any portion of it is made into sugars.

I cannot ascertain that there is any particular test by which sirups are to be distinguished from molasses, besides the general appearance of the article. The distillers say they can readily discriminate between them on inspection. I do not know of any better method of guarding against fraud under the existing laws than by submitting the article imported to the inspection of persons "expert" in such matters, in cases where fraud is suspected.

I have the honor to be, very respectfully, your obedient servant,

JAMES MILLER, *Collector,*
By E. F. MILLER, *Deputy.*

Hon. Robert J. Walker,
*Secretary of the Treasury, U. States,*
*Washington, D. C.*

No. 4.

CUSTOM-HOUSE, DISTRICT OF NEWBURYPORT,
*July* 9, 1846.

SIR: In reply to yours of June 27, I would state that to my knowledge no frauds upon the revenue have ever been attempted in this district by the importation of sirup as molasses. We have but few importations of molasses into this district, and the quality is generally of a low or medium grade.

The most effectual method of detecting such frauds would, in my opinion, be to submit the suspected article to a chemical test.

I have the honor to be, yours, respectfully,
WILLIAM NICHOLS, *Collector.*

Hon. R. J. WALKER,
*Secretary of the Treasury,*
*Washington, D. C.*

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No. 5.

COLLECTOR'S OFFICE, DISTRICT OF NEW BEDFORD,
*July* 2, 1846.

SIR: In compliance with the inquiry in your letter of June 27 last, in regard to "any cases of frauds of the kind referred to in the resolution of the Senate of the United States, committed or attempted at this port on the importation of sirups as molasses, with my views as to the measures necessary to guard against the recurrence of such frauds," I have the honor to report, that no attempt has been made, for many years past, to import sirup of any kind into this district from abroad. The only molasses imported into this district, for more than two years past, was the cargo of the barque Cora, from Matanzas, on account of William L. Baker, entered March 14 last. I have conferred with John Fuller, the inspector, who inspected and weighed this cargo. He has had much practical experience as a grocer in molasses and sirups from the West Indies, made from sugar or cane, and has a distinct recollection of the cargo in question. He carefully examined every hogshead, and does not hesitate to pronounce that it contained no improper ingredient of sugar; that it was purely molasses of a light kind and low price, and as such was sold in this market.

Mr. Fuller further reports to me, that, on proper inspection, he should have little or no difficulty in detecting any fradulent attempt to pass sirup composed in part of sugar for molasses; that all the molasses imported here since 1839 has passed under his personal observation as inspector, and that he has no reason to believe any such fraud has been attempted here in that time.

Having confidence in his judgment and fidelity, I have therefore respectfully to report to you, on this branch of the subject, that no fraud of the kind referred to has been recently attempted in this district.

In regard to measures necessary to guard against the recurrence of the frauds contemplated in the resolution of the Senate of June 26, I would respectfully state, that I have taken pains to make inquiry among grocers, and others engaged in the traffic of molasses and sirup.

Considerable quantities of sirup from the West Indies are imported into certain districts, principally the large ports of Boston and New York. Some sirup is imported *eo nomine* from Nuevitas and other places, and pays the regular duty, and it commands 5 to 10 cents a gallon over good merchantable molasses. But it is supposed here that considerable quantities of sirup are imported into the country under the denomination of molasses, and at the low rate of duty, but which, in fact, contain a large per centage of sugar; but this is a matter of inference only, our dealers having no positive knowledge of the abuse.

Experienced grocers are aware that sometimes an article which, on first being rolled on shore from the vessel, appears to be a heavy kind of molasses, after being left at rest precipitates a quantity, more or less, of sugar, which may be used as such for many purposes. It is said to be no uncommon practice, in large cities, whether imported as sirup or molasses, to reserve this article until it *settles down*: the upper portion is then drawn off, and sold for sirup or molasses, and the residuum to sugar refiners and others as an inferior kind of sugar.

Dealers here generally agree the varieties of molasses are so infinite, that while *in some cases* it would be difficult to decide whether a lot ought to be classed as sirup or molasses, or whether any lot entered as molasses contain any unlawful portion of sugar; yet they are of opinion, that *in most cases* the true character of the article may be ascertained by any competent inspector, without any chemical analysis, by merely sounding the cask with a stick.

The only means of guarding against this kind of fraud, that occurs to me, (presuming that the officer is familiar with the article,) is to enjoin the most rigid scrutiny in the discharge of his duty. This scrutiny should extend, not only to the upper stratum, but more particularly to the bottom of the cask; and if any undue proportion or consistency of residuum be formed, to report the case to the collector for special investigation. If any reasonable suspicion of fraud exists, it might be well to reserve the case for a reasonable time to test the character of such residuum as might be formed in the cask by the settling process. A proper attention to this service is probably all that could be done, under existing laws, to protect the revenue from this kind of fraud.

Possibly it might be worth while for the department to institute an inquiry whether the mode of weighing and appraising molasses be uniform in all the districts. In the process of fermentation, for instance, each cask contains much froth. After a cask has been gauged, and its capacity in gallons ascertained, a gallon is weighed to ascertain the weight of the whole. When the cargo inspected here, in March, was under inspection, it became a question for adjustment, what allowance ought to be made for froth. It occurred

to me, at the time, that there might be some honest difference in the practice of different districts. I directed the inspector to exercise his best judgment in coming to a just estimate of the actual weight.

Whether any improper favor be shown anywhere in estimating the froth, or in deciding whether an article be sirup or molasses, for the purpose of attracting business in any particular direction, I have no means of knowing beyond the limits of this district.

What legislative remedy, if any, would be applied to the case with advantage, is a difficult question. The importer's oath appears sufficiently comprehensive, and the penalty for violating the law is ample. The only common standard of admeasurement applicable to sugar and molasses appears to be weight, as now provided by law. It might lead to much general discontent to tax the same rate on sugar and molasses. The safer mode seems to be to fix reasonable rates to each, and put the responsibility of violating the law on the importer, subject to a rigid investigation of the officers of the revenue in all cases.

Knowing, sir, that you wish to respond promptly to the call of the Senate, I submit, with some haste and diffidence, these imperfect views to you, as embodying all that I am now prepared to offer in answer to your inquiries.

I have the honor to be, very respectfully, your obedient servant,

JOS. T. ADAMS, *Collector.*

Hon. Robert J. Walker,
*Secretary of the Treasury, Washington.*

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No. 6.

Collector's Office,
*District of Providence, June* 30, 1846.

Sir: Your letter of the 27th instant, requiring me to report any cases of frauds committed or attempted at this port, as referred to in a resolution of the Senate of the United States, accompanying the same, is duly received; and in answer would inform you, that no such fraud on the importation of sirups as molasses have been committed or attempted at this port. The smaller ports (and especially this port) are not the places where frauds, such as referred to in your letter, are usually committed. Here, there are not so many cargoes landed but what every officer connected with the collection of the revenue, either from duty or from curiosity, sees both the quality and quantity of the cargo; while, at the large ports the inspection cannot be so minute, because everything is done in haste.

The best mode "to guard against the recurrence of such frauds," that now suggests itself to me, is, that it should be made the duty of the gauger to report to the collector the *particular* contents of the casks. This officer *must* examine every cask to perform his duty, and by his familiarity with the article he can, by inspection and by the use of his rod, see at once whether it contains molasses,

sirup, or a mixture of sirup and sugar; and if he finds any cask or the cargo to be different from that expressed in the permit, he should report to the collector, when, if any difference of opinion should thereby arise between the collector and consignee or owner, the public appraisers might decide the matter. This seems to me to be as sure and as short a way to remedy the evil as any that I can conceive of. It will require no additional officer or expense.

I am, yours, respectfully,

H. WILLARD, *Collector.*

Hon. ROBERT J. WALKER,
*Secretary of the Treasury, Washington City, D. C.*

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No. 7.

COLLECTOR'S OFFICE,
*New Haven, June* 29, 1846.

SIR: Yours of the 27th instant, with a copy of a resolution annexed, passed by the Senate of the United States, has been received.

It gives me pleasure to be able to state that no case of fraud or attempted fraud, in the importation of sirups as molasses, referred to in the Senate resolution, has come to my knowledge in this district, nor do I believe there has been any.

I am, sir, very respectfully, your obedient servant,

NORRIS WILCOX, *Collector.*

Hon. R. J. WALKER,
*Secretary of the Treasury, Washington, D. C.*

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No. 8.

CUSTOM-HOUSE, NEW YORK,
*Collector's Office, July* 21, 1846.

SIR: In reply to your communication of the 27th ultimo, I have the honor to enclose herewith a report from the surveyor of this port, on the alleged importations of sirup of sugar under the name of molasses.

It is evident that the merchants and dealers in the article in question call it molasses; that it is not worth more than ordinary molasses; that it does not command a higher price; and that, after the payment of duty it will not sell for 2½ cents per pound, the rate of duty chargeable on sirup of sugar.

I am, sir, yours, very respectfully,

C. W. LAWRENCE.

Hon. ROBERT J. WALKER,
*Secretary of the Treasury, Washington, D. C.*

CUSTOM-HOUSE, NEW YORK,
*Surveyor's Office, July* 20, 1846.

SIR: In compliance with your letter, enclosing a resolution adopted by the Senate of the United States, and also instructions from the Treasury Department, I have the honor to report, that some time in June last, this department was informed by letter from the Treasury Department, over the signature of W. F. Wilkins, that frauds were practised by importations in this port of *sirup* as *molasses*.

About the same period, a letter was received by me from Mr. Wilkins, conveying similar intimations; and instructions were immediately given to Inspector Cairns (who had been deputed by my predecessor to attend to this branch of the revenue service) to to take samples of the molasses, as it arrived in port, and make the necessary examination to guard against fraud (as alleged.) The report of Mr. Cairns is herewith submitted, and marked A.

Mr. Cairns was the inspector selected to take and prepare the samples of sugar and molasses, forwarded to Philadelphia in September last, for examination by Professor McCulloh, in accordance with the directions of the Treasury Department.

His experience, therefore, induced his selection, and gave me confidence in his judgment. Immediately on the receipt of the letter of the Secretary of the Treasury, enclosing the resolution of the Senate, samples of molasses were taken for examination and analysis, and Inspector Cairns directed to employ a *chemist* to analyze and ascertain the correctness of the assertion as to the frauds alluded to. An interview was had with this Mr. Wilkins, who gave the information, and who represents himself as being perfectly familiar with the subject. He (Wilkins) was also invited to attend the investigation, and to make whatever suggestions he thought would tend to insure a *minute* and *thorough* investigation.

The report of Doctor Thomas, the chemist employed to analyze the samples of molasses, is herewith submitted, marked B.

Agreeably to your instructions, and in order that full and satisfactory information should be given to the honorable the Senate of the United States, the celebrated Doct. Chilton was also employed to analyze samples of the same cargo, *marks* and *qualities*, as were analyzed by Doct. Thomas, the chemist heretofore alluded to. The result of Doct. Chilton's examination is also herewith submitted, marked C.

In the absence of any *fixed standard* for the government of this department, directing their action, and defining the per centage of crystallizable *sugar* or *matter* contained per gallon in either sirup or molasses, we have been governed by the custom established and acted upon by my predecessors in office, anxiously awaiting the coming report of Professor McCulloh, as directed by the Treasury Department, for our *future* government and action.

The importers of the molasses analyzed by Drs. Thomas and Chilton, inform me that they have this day forwarded to the Treasury Department (a copy of which they have sent me) a certificate from merchants of the highest character, who represent that "they

have examined the recent importations of molasses from Nuevitas, in which the alleged frauds are said to exist; and they pronounce it nothing but *molasses*, such as they are in the habit of purchasing from *Puerto Rico*, St. Croix, and other West India islands."

I would remark, in relation to the certificate which I have alluded to, that I have long known most of the signers as extensive dealers in the article, and know them to be *men of unquestionable integrity*, and whose experience gives to their opinions great weight.

The cargoes of molasses, from which the samples were taken and used for analyzation by Drs. Thomas and Chilton, were disposed of at auction and at private sale, by the importers, to the grocers, in small lots, at prices varying from *nineteen* to *twenty-six* cents per gallon. The sales were made, and a portion of the article consumed, previous to the receipt of the letter of the Secretary of the Treasury, enclosing the resolution of the Senate of the United States.

If frauds have heretofore existed, they are most assuredly unknown to this department. Every possible precaution has been used by this department, with a view to *prevent* and *detect fraud*, in this as well as in all other cases. I feel that I have exercised the most prompt and energetic measures to guard the revenue, and can assure the Treasury Department that the same efforts will be continued with unabated zeal.

The expenses attending these examinations are considerable, requiring the employment of those only who are acquainted with chemical analysis. It is, therefore, particularly desirable that some mode of testing, or a *standard*, should be fixed upon for the government of this department in its further action. The bills of Drs. Thomas and Chilton are herewith enclosed, amounting to ($150) one hundred and fifty dollars.

You will doubtless recollect, that under the administration of collector Van Ness, and at the commencement of yours, a person was specially employed to take samples of the different cargoes of molasses arrived in port, and to be submitted for examination at the surveyor's office.

These samples were generally examined by the surveyor and inspectors Lloyd and Cairns, who are now, and have been for a long time, detailed for sugar inspection duty.

The Treasury Department deemed the employment of the person to take samples unnecessary; and it was, accordingly, discontinued.

Officers Lloyd and Cairns are constantly engaged in the discharge of the duty particularly assigned to them, and not unfrequently require an additional inspector to assist them. Consequently, they are unable to attend to the *special duty* of examining and sampling molasses.

The cargoes of molasses now arriving at this port are sent up to the city in "lighters" or small craft from the "quarantine ground" at Staten Island, and are landed at Brooklyn and various other points of our extensive *water front*. It will require one person,

(and frequently an assistant,) to procure samples, and examine the cargoes at the different *landing places* above mentioned.

As this particular duty is by law under my immediate supervision, I respectfully solicit your approbation to select some competent person to perform it for *at least* the continuation of the quarantine regulations.

I have the honor to be, with great respect, yours, &c.,

ELIJAH F. PURDY, *Surveyor.*

Hon. C. W. LAWRENCE, *Collector, &c.*

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A.

NEW YORK, *June* 29, 1846.

SIR: Having been assigned to the duty of causing an analysis of molasses or sirup imported into this district from Nuevitas, Cuba, I have the honor to report that three samples were procured and submitted to Mr. James Thomas, a chemist of this city, for the purpose of scientific examination. His report is now before the department, giving the results of the various experiments, and the opinion that two of these samples, containing from 56 to 58 per cent. of crystallizable sugar, are to be considered "sirup."

I must, however, state that this gentleman has been previously employed by this department to make analysis of samples of precisely the same kind and quality as in the present instance, and has not been able to detect sugar that would give them the character of "sirup."

I would also remark that at a previous date this department had caused a large quantity of the same kind and quality of molasses or sirup to be tested by a practical refiner. That similar samples were sent for analysis to Professor McCulloh, of Philadelphia, by direction of the comptroller, at Washington, and that they have also been submitted to men of high scientific attainments in this city, all of whom have uniformly agreed in the opinion that the article was not sirup.

In view of these facts, I beg leave, respectfully, to suggest the expediency of causing samples of the same kind to be analyzed by different persons, to the end that the true character of the subject under consideration may be ascertained.

Respectfully submitted.

JOHN T. CAIRNS, *Inspector.*

To ELIJAH F. PURDY, Esq.,
*Surveyor of the port of New York.*

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*Analysis of molasses or sirup of*——.

Sample marked JG, imported in brig Brothers, from Nuevitas, Cuba, May 23, 1846, by Brett & Vose, and analyzed by James

Thomas and James R. Chilton, chemists. It will be seen by their reports respectively, that in this sample they very nearly agree in their experiments. Mr. Thomas reports 58.25 per cent., and Mr. Chilton 58.20 per cent. of crystallizable or cane sugar.

Sample described by Mr. Thomas as No. 1, and by Mr. Chilton as AR, C$^{s}$, is one and the same article, imported in brig Tonquin from Nuevitas May 19, 1846, by Holt & Owen. In this sample Mr. Thomas reports 56.55 per cent., and Mr. Chilton 40.4 per cent. of crystallizable or cane sugar.

Sample described by Mr. Thomas as No. 2, imported in brig United States from St. Croix, June 6, 1846. In this he makes to yield 50.63 per cent. of crystallizable or cane sugar.

Sample described by Mr. Thomas as No. 3, imported in brig Overman, June 4, 1846, by P. Harmony, Nephew & Co., from Ponce, P. R. In this he reports 49.54 per cent. of cane sugar.

Sample described by Mr. Thomas as No. 4, from New Orleans. In this he reports 46.52 per cent. of crystallizable or cane sugar.

JOHN T. CAIRNS, *Inspector.*

NEW YORK, *July* 18, 1846.

—

B.

NEW YORK, *June* 20, 1646.

GENTLEMEN: The undersigned would respectfully represent, that having been selected by Captain John T. Cairns to examine three samples of imported molasses or sirup, he respectfully reports the results of the examination.

The sample marked JG is of a light color, pleasant taste, without any empyreuma, and from its sensible qualities, seems to be a very superior article, if it is molasses. This sample, when submitted to a qualitative examination, appears to contain both crystallizable or cane sugar and uncrystallizable sugar or molasses, also called granular sugar; a portion heated with diluted solution of potassa gave the well known brown color indicative of granular sugar or molasses; another portion heated with diluted sulphuric acid showed the presence of cane sugar by producing a brown color, and after some time an insoluble brown matter was deposited, indicative of the presence of cane sugar.

Two equal portions of this sample were examined by Mr. Trommer's test; one portion was merely diluted with water; the other, also diluted with water, was boiled with a drop or two of sulphuric acid, to convert any crystallizable sugar it might contain into molasses; these two equal portions, thus treated, were separately examined by Mr. Trommer's test, which consists in adding to the saccharine solution to be examined a few drops of a solution of sulphate of copper, (blue vitriol,) and afterwards some solution of potassa, and heating the mixture to nearly a boiling temperature; the uncrystallizable sugar or molasses contained in the liquor reces the salt of copper, and precipitates a red oxide of that

metal, while the crystallizable sugar contained in the liquor does not change the properties of that salt. The portion of this sample merely diluted with water gave a precipitate of red oxide of copper, but the other portion that had been treated with sulphuric acid gave a most abundant precipitate of the oxide—proving satisfactorily the presence of cane sugar and molasses in this sample, marked JG.

The specific gravity of this sample is 1,360 at 60° of Fahrenheit. A small quantity of this sample in a capsule, or little cup, was placed under a glass bell or receiver, also a cup half full of strong sulphuric acid, and a slight vacuum maintained within the glass bell; the sulphuric acid by its avidity for moisture kept the space within perfectly dry, and the sample soon lost enough of its water of solution to become a semifluid mass of crystals of sugar, from which the molasses would easily separate. This experiment was often repeated and with uniform success.

The sample marked SV is light colored and of a good taste; it is rather heavy, compared with the other two samples, its specific gravity being 1.404. Submitted to the same tests as the former sample, it gave similar results, only the quantity of uncrystallizable sugar appeared to be much greater. When placed under the glass bell, in the same circumstances as the former sample, it would not crystallize, and no sugar could be obtained from it by this means.

The sample marked No. 1 is rather dark colored, it gave similar results to the sample JG; its specific gravity is 1.364.

The *quantitative examination* of these *samples* and obtaining the absolute per centage amount of cane sugar and molasses, separately, was a problem beset with great difficulties. The only course likely to be successful appeared to be one that should be based upon Mr. Trommer's discovery, before alluded to. I now proceed to give the method followed in this investigation, so that if any error has been committed it may be open to correction.

*Preparation of the test.*—Two ounces of sulphate of copper (blue vitrol) are dissolved in one point of water; in a separate vessel dissolve one ounce of bitartrate of potassa (cream of tartar) and four ounces of potassa (caustic potash) in one pint of water. Well mix these solutions, and filter the fluid from the dregs. It will be of a fine blue color, if rightly made; as thus made, the test will not, however, give uniform results when tried on equal weights of pure sugar converted into molasses. The test liquor requires to be heated to boiling, and filtered from some oxide of copper separated by the boiling. It will now give uniform results. It requires care in heating, as it is apt to bump or boil over. The test so prepared was the one made use of in this investigation.

*Stuart's best loaf sugar* was the standard of comparison, being perfectly free from molasses. Twenty grains of this sugar dissolved in water and boiled for fifteen or twenty minutes, with a few drops of sulphuric acid, gave with the copper test in slight excess thirty-three grains of oxide of copper. So that every 1.65 of oxide obtained equals one of pure sugar in solution.

*Quantitative examination of sample JG.*—Took 20 grains of this sample, diluted it with water, then put in a slight excess of the test, heated it to boiling, let it cool, decanted the supernatant fluid from the precipitate, washed it several times and dried it. Weight of dry red oxide of copper obtained 4.5 grains, equal to 13.7 per cent. of uncrystallizable sugar or molasses in 100 parts of this sample by weight. Another 20 grains were boiled with a few drops of sulphuric acid and about a gill of water, to convert the cane sugar into molasses. This gave 23.75 grains of oxide of copper, equal to 71.95 per cent. for the whole saccharine matter contained in this sample, and gives 58.25 per cent. for the cane sugar.

*Quantitative examination of sample SV.*—Twenty grains of this sample gave 10.75 grains of oxide of copper, equal to 32.6 per cent. for the molasses it contains; another 20 grains converted into molasses, by the action of sulphuric acid, gave 72.7 per cent. for the whole of the saccharine matter contained in this sample.

*Quantitative examination of sample No.* 1.—This sample gave 15.7 per cent. for the molasses it contained, and when the whole was converted into molasses it gave 71.25 per cent. for the whole of its saccharine matter, giving 56.55 per cent. for the crystallizable sugar it contains.

To the best of my judgment, I should say that the samples JG and No. 1 are *sirup*, because they contain so small an amount of uncrystallizable sugar, and the readiness with which they can be made, by simple means, to yield good sugar.

This sample SV must be called molasses, for it yields a large proportion of uncrystallizable sugar, and cannot be made by simple means to yield sugar.

The simplest method by which a person might distinguish good cane sirup from molasses and spoiled sirup would be by a small apparatus, on the principle of the air pump, modified to suit this peculiar purpose. A more abtruse, and perhaps troublesome, method would be by the circular polarization of light; for a saccharine solution that should cause left handed polarization would, probably, be of little use for the production of sugar. It is not to be concealed, however, that good cane sirup, boiled till it should cause left handed polarization, would be in a fit state for the manufacture of lemon and other sirups, and for many other purposes.

The above is most respectfully submitted.

JAMES THOMAS, *M. D.*

To Cornelius W. Lawrence, *Collector, and* Elijah F. Purdy, *Surveyor of the United States Revenue Department for the city and port of New York.*

—

New York, *July* 9, 1846.

Sir: The undersigned respectfully represents that he has, by your orders, examined three samples of molasses, given to him by Captain John T. Cairns for that purpose.

Sample No. 2 was of the specific gravity of 1.373, and it contained 18.17 per cent. of molasses or uncrystallizable sugar, and 50.63 per cent. of crystallizable sugar or cane sugar. The whole quantity of saccharine matter it contained was 68.8 per cent. It would produce sugar by simple means.

Sample No. 3 was of the specific gravity of 1.376; it gave of molasses 20.46 per cent., and 49.54 per cent. of cane sugar. The whole quantity of saccharine matter it contained was 70 per cent. It would produce sugar by simple means.

Sample No. 4 was of the specific gravity of 1.365; it contained of molasses or uncrystallizable sugar 18.88 per cent. and 46.52 per cent of crystallizable or cane sugar. The whole amount of saccharine matter it contained was 65.4 per cent. It would, with some difficulty, produce sugar of a very dark color, almost as dark as the molasses itself. This sample contained a considerable quantity of lime and other inorganic matters.

For the methods followed in the examination of these samples I respectfully refer you to my former communication to you relative to this subject, in which the methods followed in these analyses are detailed, and, therefore, it is unnecessary to repeat them here.

The above is most respectfully submitted.

JAMES THOMAS, *M. D.*,
*39th street, near 8th avenue, New York.*

To ELIJAH F. PURDY, *Surveyor of the United States Revenue Department for the city and port of New York.*

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C.

NEW YORK, *July* 17, 1846.

SIR: I have carefully analyzed the two samples of "molasses" which you sent me, and find them to contain as follows:

Sample marked JG.—The specific gravity, at 60° Fahrenheit, is 1.341. One hundred parts by weight contain—

| | |
|---|---|
| Crystallizable or cane sugar | 58.20 |
| Uncrystallizable sugar | 8.43 |
| Water | 16.20 |
| Mucilage, extractive matter, &c. | 17.17 |
| | 100. |

Sample marked AR, C[a].—The specific gravity, at 60° Fahrenheit, is 1.333. One hundred parts by weight yielded.

| | |
|---|---|
| Crystallizable or cane sugar | 40.4 |
| Uncrystallizable sugar | 10.0 |

| | |
|---|---|
| Water | 12.5 |
| Mucilage, extractive matter, &c | 37.1 |
| | 100. |

As near as could be determined, by actual weights of the samples furnished, one gallon of the sample marked JG would weigh 11 lbs. 11 ozs. avoirdupois; and one gallon of the sample marked AR, C$^{a}$ would weigh 11 lbs. 12 ozs. avoirdupois.

The methods of analysis by which these results were obtained, were—

1st. By treating a known weight of the liquid with trisacetate of lead, to separate the mucilage, extractive matter, &c. The clear solution, thus obtained, was repeatedly passed through fresh prepared bone charcoal to separate the excess of oxide of lead. It was then subjected to evaporation in vacuo until crystallization was effected. The crystalline mass was treated with absolute alcohol, which dissolves the uncrystallizable portion.

The 2d method was a modification of the one proposed by M. Barreswil,* viz: by treating a given weight of the saccharine fluid by Trommer's copper test, to determine the proportion of uncrystallizable sugar. The whole of the saccharine matter in another similar weight of the fluid is to be converted into uncrystallizable sugar, by gently boiling with a few drops of sulphuric acid. Then, by treating it with the copper test, the proportion is determined; and, by subtracting what was obtained from the first portion, the amount of crystallizable sugar is obtained.

The results which I have given are the mean of what I obtained by these different modes of analysis.

Very respectfully,

JAMES R. CHILTON.

ELIJAH F. PURDY, Esq.,
*Surveyor of the port of New York.*

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No. 9.

21 FRANKFORD STREET, NEW YORK.
*June* 22, 1846.

SIR: After a month of very tedious investigation, we have this day given in to the surveyor of this port a copy of the analysis, &c., of Nuevitas sirup which was entered as molasses in the custom-house. The chemist proves two of the samples to contain 55 per cent. of granular or cane sugar by the heat analyses, and that it is decidedly *sirup*. The surveyor has ordered other samples of sirup to be analyzed, which is from other places.

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* Chemical Gazette, No. 52, December 16, 1844.

We have also laid down in the report plans how to detect sugar in disguise. I trust you will now see that the chemist and myself have done our duty. Further, if I could do more, I would. I trust, honored sir, you will order me some remuneration for labor and loss of time, having worked hard night and day in this matter. Others are paid by the custom-house; and, although they are aware how I have worked, yet I do not apply to them, but to your honorable self, for some reward for my labor and perseverance. I trust you will give me an early reply.

In the interim, I am, sir, your very humble and obedient servant,

WILLIAM F. WILKINS.

To the Hon. R. J. WALKER,
*Secretary of the Treasury.*

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CUSTOM-HOUSE, NEW YORK,
*Collector's Office, July* 24, 1846.

SIR: I return Mr. Wilkins's letter to you of the 22d ultimo, referred to me for a report.

In consequence of the representations of Mr. Wilkins, the surveyor caused an analytical examination to be made of the article referred to, and informed him that he could be present at such examination. I believe he did attend. The report of the surveyor, communicating the result, was transmitted to you on the 21st instant.

Messrs. Holt & Owen, of this city, entered at this office, on the 15th instant, a cargo of molasses, per brig Clarissa, from Nuevitas. I informed them that I should not authorize its delivery except they deposited an amount sufficient to cover the duties, if, on examination, it should prove to be *sirup of sugar*. They declined making such deposite, and I directed the retention of the molasses until it was fully examined, and we were satisfied of its character.

The surveyor consulted Mr. Chilton on the subject, and received from him the enclosed letter giving the results of his previous examinations.

We have made diligent inquiry of merchants and dealers in molasses, and, in every instance, the answer has been that the proper name of the article is molasses.

Mr. Havemeyer, the late mayor of this city, has been extensively engaged in the sugar trade, and is one of our most independent and intelligent citizens, and particularly well informed in reference to the laws in relation to sugar and molasses. I enclose my letter to him, and his reply.

I also enclose my letter to the United States appraisers, with their reply.

I, therefore, came to the conclusion that the owners were entitled to receive the molasses upon paying 4½ mills per pound duty, and, consequently, directed its delivery.

It is evident that, if I am to be governed by its *commercial*

*name*, the article imported from Nuevitas as molasses is rightly named, and should be assessed accordingly—4½ mills per pound.

If, however, its name is to be ascertained and decided by analysis, some determinate standard should be fixed upon and promulgated.

I have the honor to remain, sir, yours, very respectfully,

C. W. LAWRENCE.

Hon. ROBERT J. WALKER,
*Secretary of the Treasury, Washington.*

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NEW YORK, *July* 21, 1846.

DEAR SIR: I have for the last three or four years past analysed various samples of molasses which have come to this port from Cuba and other ports of the West Indies, and have almost uniformly found them to contain from 65 to 75 per cent. of pure saccharine matter, but not all in a crystallizable state. The proportion of crystallizable or cane sugar contained in the samples of Nuevitas molasses which I have heretofore analyzed, was very nearly the same as contained in the samples which I analyzed for you recently.

Very respectfully, yours,

JAMES R. CHILTON.

ELIJAH F. PURDY, Esq.

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CUSTOM-HOUSE, NEW YORK,
*Collector's Office, July* 22, 1846.

SIR: I have to beg the favor of you to examine the cargo of molasses imported by Messrs. Holt & Owen in the brig Clarissa, from Nuevitas. Is it, in your opinion, molasses which is intended by the tariff act of 1842 to pay duty at the rate of 4½ mills per pound? Or is it the sirup of sugar, which would pay 2½ cents per pound—equal to about 29 cents the gallon?

I am, sir, yours, very respectfully,

C. W. LAWRENCE.

Hon. W. F. HAVEMEYER, *New York.*

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NEW YORK, *July* 22, 1845.

DEAR SIR: According to your request, I have examined, in the surveyor's office, a number of samples of molasses said to have been taken from the cargo of the brig Clarissa, from Nuevitas, and consigned to Messrs. Holt & Owen, and have no hesitation in stating, as my opinion, that the same are samples of Nuevitas molasses, known in the market as such, and subject to duty as molasses, and not to duty as sirup of sugar.

I have the honor to remain your obedient servant,

W. F. HAVEMEYER.

Hon. CORNELIUS W. LAWRENCE,
*Collector, &c.*

CUSTOM-HOUSE, NEW YORK.
*Collector's Office, July* 22, 1846.

SIRS: I have to request that you will examine and report to me on the cargo of molasses imported by Messrs. Holt and Owen in the brig Clarissa, from Nuevitas. Is it, in your opinion, molasses which is intended by the act of 1842 to pay duty at the rate of 4½ mills per pound? Or is it the sirup of sugar which would pay 2½ cents per pound—equal to about 29 cents the gallon?

Yours, very respectfully,
C. W. LAWRENCE,

To the PRINCIPAL APPRAISERS
*of the port of New York.*

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APPRAISERS' OFFICE,
*New York, July* 23, 1846.

SIR: We have examined various samples called molasses, imported by Messrs. Holt & Owen, in the brig Clarissa, from Nuevitas, and report that it has been known as molasses; is now known as molasses, and nothing else; and in our opinion, is justly liable to a duty of 4½ mills per pound, under the tariff of 1842, and no more.

Most respectfully,
G. W. POMEROY,
SAM. J. WILLIS.

Hon. C. W. LAWRENCE, *Collector.*

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No. 10.

COLLECTOR'S OFFICE,
*District of Philadelphia, June* 30, 1846.

SIR: Yours of the 27th, transmitting a resolution of the Senate of the 26th instant, in relation to frauds supposed to have been committed upon the revenue by the importation of sirups as molasses, has been received. In reply thereto I beg leave to state, that on the 10th August, 1843, an elaborate scientific report upon the subject (to which I beg leave to refer you) was transmitted to your department by my predecessor.

Since that period, especial care has been taken to detect anything in the nature of the frauds referred to in the resolution of the Senate. The records of this office furnish no evidence upon which to ground even a suspicion of any evasion of the revenue laws in regard to the article in question; nor do I believe that any attempt to commit such frauds could possibly escape the vigilance of our officers.

Very respectfully, your obedient servant,
HENRY HORN, *Collector.*

Hon. R. J. WALKER,
*Secretary of the Treasury.*

No. 11.

COLLECTOR'S OFFICE,
*Baltimore, June* 29, 1846.

SIR: I have the honor to acknowledge the receipt of your letter of the 27th instant; and, in reply, state that no cases of frauds mentioned in the resolution of the Senate of the 26th instant, have been committed or attempted at this port, on the importation of sirups as molasses. This article of merchandise is subject to the particular inspection of the surveyor of this port, who reports to me as above stated.

With great respect, sir, your obedient servant,

W. H. MARRIOTT, *Collector.*

Hon. R. J. WALKER,
*Secretary of the Treasury of the United States,*
*Washington City.*

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No. 12.

CUSTOM-HOUSE, NORFOLK, *July* 1, 1846.

SIR: I have received your letter of the 27th ultimo, submitting a resolution of the Senate of the United States of the day previous, in relation to the frauds reported to have been committed by recent importations, from the West India islands, of sirup as molasses, &c., and directing a report to be made of any cases of frauds of the kind referred to, committed or attempted at this port.

In reply, I have the honor to state that there is no reason to believe or to suspect that any such cases have occurred at this port.

I am, very respectfully, your obedient servant,

CONWAY WHITTLE, *Collector.*

Hon. R. J. WALKER,
*Secretary of the Treasury.*

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No. 13.

COLLECTOR'S OFFICE, ELIZABETH CITY,
*July* 6, 1846.

SIR: In reply to yours of the 26th ultimo, I have to state that, to the best of my knowledge, there has been no attempt at this port to defraud the revenue by the importation of "sirups as molasses;" consequently, I have formed no views on the subject of guarding against the recurrence of such frauds as are referred to in the resolution of the Senate of the United States, annexed to your letter.

Very respectfully, your obedient servant,

WM. D. PRITCHARD, *Collector.*

Hon R. J. WALKER,
*Secretary of the Treasury, Washington, D. C.*

No. 14.

CUSTOM-HOUSE, WASHINGTON, N. C.,
*July* 6, 1846.

SIR: In answer to your letter of the 27th of June, I have to say I am not aware of any cases of fraud having been committed in this district by the importation of sirups as molasses; and I deem it proper to state that I apprehend but little danger of any such being committed, there being no refineries in this part of the State, the importation and the consumption of molasses being too small to offer inducements to violate a law that could so easily be detected. I shall, notwithstanding, endeavor to keep vigilant watch in person, so far as practicable, and promptly report, if any attempt be made within my knowledge.

I am unable, at this moment, to suggest any measure that would be likely to defeat an attempt at fraud of this nature, except it be by levying such duty as would make it pay in proportion to its value with sugar, and vigilance and strict enforcement of the revenue laws.

I have the honor to be, very respectfully, your obedient servant,
JAMES K. HATTON, *Collector.*

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No. 15.

COLLECTOR'S OFFICE,
*Charleston, July* 1, 1846.

SIR: I have the honor to acknowledge the receipt of your letter of the 27th June, with the resolution of the Senate, asking for information as to frauds which may have been attempted o. mitted in this port by the importation of sirups as molasses.

Nothing has occurred here inducing me to believe that any such fraud has been either attempted or committed. There are no sugar refineries or manufactories in this vicinity, and the sirup here would be useless to the importer.

If the molasses hogsheads were properly gauged, and the molasses examined and weighed carefully, I should presume that it would not be difficult to detect any attempts to introduce sirups as molasses. As the former article, however, is not brought into this port, I have no experience as to its appearance or properties, and could offer conjectures only as to the proper mode of detecting it if attempted to be introduced fraudulently.

I have the honor to be, with great respect, your obedient servant,
W. J. GRAYSON, *Collector.*

HON. R. J. WALKER,
*Secretary of the Treasury.*

No. 16.

CUSTOM-HOUSE, *Savannah, July* 3, 1846.

SIR; Your letter of the 27th ultimo, with the resolution of the Senate of the United States annexed, relating to the frauds reported to have been committed by recent importations from the West India islands into ports of the United States, has been received.

In reply, I have the honor to state that no case of fraud of the kind referred to has been committed or atempted at this port on the importation of sirup as molasses.

Mr. Tupper, the weigher and gauger, assures me that no fraud of the kind has been attempted here. He was formerly engaged extensively in commercial business, and he says, should a case occur, he could rely with confidence upon his practical experience and knowledge of the articles (sirup and molasses) to detect the same without doubt or hesitation.

I am not aware of any test that I could suggest that would be equal to the practical experience and knowledge of the examining officer, whose vigilance should be particularly directed to the subject.

I am, very respectfully, your obedient servant,

W. B. BULLOCK, *Collector.*

Hon. R. J. WALKER,
*Secretary of the Treasury.*

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No. 17.

COLLECTOR'S OFFICE,
*Mobile, July* 6, 1846.

SIR: I have the honor to report, in answer to your favor of the 27th ult., that no frauds have occurred in the introduction of sirups as molasses into this port, at least during the last fiscal year; for I find on examination that no molasses have been imported during that time from the West Indies.

With respect to the measures necessary to guard against the recurrence of such frauds, I beg leave to say that my attention has not been sufficiently drawn to this subject to enable me to make any practical suggestions. The subject is one of much difficulty. "Sirup may be so disguised as to render it extremely difficult, if not impossible, for even experienced sugar refiners to decide whether it be molasses or not." (Professor McCulloh, Senate document, 28th Congress, 2d session, No. 165.)

The best general remedy, however, suffer me to remark, not only for this, but for all other attempts to defraud the revenue, would be

the adoption of the moderate scale of duties heretofore recommended by you to Congress.

I am, sir, very respectfully, your obedient servant,

JAMES E. SAUNDERS, *Collector.*

Hon. R. J. WALKER,
*Secretary of the Treasury.*

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No. 18.

SURVEYOR'S OFFICE,
*New Orleans, July* 16, 1846.

SIR: Within the last sixty days there have been several large importations of molasses into this port, and two of the cargoes have been subjected to a chemical analysis by an able professor, and found to be molasses and not sirup.

Noticing a call upon the Treasury Department for information on the subject of the fraudulent importation of sirup as molasses, I have thought proper to communicate to the department that no such frauds are believed to have been practised in this port by importers of molasses.

Very respectfully, your obedient servant,

DAVID HAYDEN, *Surveyor.*

Hon. R. J. WALKER,
*Secretary of the Treasury, Washington, D. C.*

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No. 19.

CUSTOM-HOUSE, APALACHICOLA,
*July* 20, 1846.

SIR: In reply to your letter of the 27th of June last in regard to the fraudulent importation of sirups as molasses, I have to state that no such evasions of the law have been attempted at this port. The entire importations of molasses made during the past year at this place have been regularly gauged and weighed, and there could have been no mistake in regard to its true character.

Respectfully, your obedient servant,

SAML. W. SPENCER, *Collector.*

Hon. R. J. WALKER,
*Secretary of the Treasury, Washington.*

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No. 20.

NEW YORK, *July* 20, 1846.

SIR: The enclosed letter will inform you something of the character and the object in view which the Englishman (Wilkins) has

in writing to the Treasury Department about frauds on the revenue by the importation of molasses. We have been harassed of late by the detention of our molasses for several days on the dock after its sale to the grocers, causing us great inconvenience and expense, and disappointment to the purchasers awaiting the result of the chemical analyses ordered by the collector. Recently he has employed two eminent chemists (Messrs. Chilton and Thomas) to analyze imported molasses; the first analyzed Nuevitas (Cuba) molasses, and the second Puerto Rico and St. Croix molasses, and both tests have given the same results.

The Nuevitas molasses consigned to us, marked AR, C , and which was analyzed by Professor Chilton, after keeping it on the wharf over twenty days without being able to sell it, we sent to auction, and it was sold by the auctioneers, Messrs. D. C. & W. Pell, to the grocers, at 19½ and 20 cents per gallon, at four months' credit. A better proof cannot be had of the inferiority of this molasses. We do hope, sir, that after you are satisfied of the character of this Wilkins, and of the recent chemical tests of the different qualities of molasses that have been analyzed by order of onr collector, something will be done to prevent the frequent vexatious delays we are constantly subjected to after our molasses is landed on the dock and sold. All our recent importation of molasses already sold to different grocers, lays exposed on the dock to the weather, and risk of being stove by carts. The collector won't allow the purchasers to take it away; it is awaiting your decision which we do hope will come by *return of mail*, or else the purchasers may decline taking it, and we thus lose the sale.

The average price Nuevitas molasses has brought in this market for the last ten years is about 25 to 26 cents per gallon, which is a little under that brought from Puerto Rico.

The object this Englishman (Wilkins) has in causing all this vexatious trouble is, to get money out of some one. He has tried to levy *black mail* upon us; has called on the surveyor of this port for the result of the chemical analyses of the molasses, and styles himself the representative of the Louisiana planters, from whom he expects large remuneration for his services in guarding the revenue from fraud.

The enclosed certificate from our principal grocers, to whom we have been in the habit of selling Nuevitas molasses, will give you their views about said article.

Very respectfully,

HOLT & OWEN.

Hon. ROBERT J. WALKER,
*Secretary of the Treasury.*

Every collector and surveyor of this port for the last fourteen years have had the molasses from Nuevitas analyzed, and were convinced to their satisfaction that it was nothing but molasses.

We, the undersigned, grocers of the city of New York, do certify that we have examined all the recent importations of Nuevitas

(Cuba) molasses, and have bought and sold said article for many years; and do pronounce it nothing more than molasses, such as we are in the habit of buying from Puerto Rico, St. Croix, and other West India islands.

NEW YORK, *July* 20, 1846.

| | |
|---|---|
| A. Hubbard & Co. | Burdick & Silkman |
| Wm. E. Bird | Edwin Smith |
| W. & G. C. Woodhull | Beers & Bogart |
| Oliver Corwin & Co. | Medad, Platt & Co. |
| Craig & Lane | Thos. Morrell |
| Penfold & Schuyler | B. H. Howell & Co. |
| Roberts & Spencer | Jno. J. Moore & Co. |
| W. G. Streting & Co. | Arcularius & Bonnett |
| Evans & Almy | Williams & Hamley |
| Southworth, Litchfield & Beach | Henry K. Morgan |
| Beale, Melich & Delbit | Coman, Hopkins & Co. |
| Danl. F. Youngs | C. & L. Denison & Co. |
| Datro, Miller & Co. | P. G. Arcularius & Co. |
| Hopkins Hawley | |

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NEW YORK, *July* 18, 1846.

SIR: Our attention has been called to several communications in the public papers in relation to frauds on the revenue, by the importation of sirup molasses under the name of molasses; and as some importance has been attached to the communications made to you on the subject, we deem it our duty to make you acquainted with the character and pretensions of your informant.

In the month of February last, an Englishman named W. F. Wilkins called on us, and represented himself as being a sober and industrious man, and that he understood managing steam-engines on sugar estates; had been engaged on the extensive estate of Monsieur Millardon, in Louisiana; was perfect master in making a splendid article of Muscovado sugar, &c.; and said if we would send him out to Cuba, with a recommendation to our friends there, he was sure of teaching them to make Muscovado sugar equal to any St. Croix. Having then a vessel about to sail for Nuevitas, we told him that we would give him a free passage out and home, with letters to our friends. He then begged of us to let him have $50 to leave with his wife, as she was, as he said, without means. He seemed so anxious to go, and talked so much of his thorough knowledge in sugar-making, that we finally let him have the $50; but on the following day regretted we had done so, as we found Mr. Wilkins was not the sober man he had represented himself to be; he was in a state of intoxication till the vessel sailed.

On the day of his arrival at Nuevitas he got drunk, and according to all accounts lay in that state on the wharf the greater part of the time whilst the vessel was loading. During some of his sober moments he went on the plantation of one of our friends, to

whom we had given him a letter, and he placing great confidence in the sugar-maker we had so highly recommended, delivered over to him his train of kettles, that he might have an opportunity to go on and make the splendid sugar he boasted so much of being able to make. In a very short time the planter plainly saw that Mr. W. did not at all understand sugar-making. He wrote to us that Wilkins had caused him about $600 damages, by burning the sugar black as tar, and came very near ruining his sugar kettles. When Wilkins found out he could not do anything there, he again gave himself up to drinking, and was drunk nearly all the while till the time of the vessel's sailing; and after his arrival here we saw him staggering out of the cabin. This said Wilkins wrote us a letter from Cuba, which he brought here himself, wherein he says: "*My intentions were to have made as much money out of the planters during crop as would have carried myself and wife to London, and a little to spare. In this I am disappointed—that is, directly; but I am certain of making money* INDIRECTLY *by the trip, which may in the long run abundantly repay me for the said trip.*"

You thus see what the object of this fellow is in getting the collector of the port to have Cuba molasses analyzed by chemists —molasses that the sugar-boilers in this city seldom buy, because, they say, it yields so little sugar.

Respectfully submitted by your most obedient servants,

HOLT & OWEN,
156 *South street.*

To the Hon. R. J. WALKER,
*Secretary of the Treasury, Washington.*

29th Congress, 2d Session. [SENATE.] Executive,

# REPORT

OF THE

# SECRETARY OF THE TREASURY,

COMMUNICATING

*A report of scientific investigations relative to the chemical nature of saccharine substances, and the art of manufacturing sugar; made, under the direction of Professor A. D. Bache, by Professor R. S. McCulloh.*

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March 1, 1847.

Ordered to be printed, and that 5,000 additional copies be printed for the use of the Senate

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Treasury Department,
*February* 27, 1847.

Sir: I have the honor to transmit herewith, for the information of the Senate, a letter from Professor A. D. Bache, communicating a report of scientific investigations relative to the chemical nature of saccharine substances and the art of manufacturing sugar, made under his superintendence, by Professor R. S. McCulloh.

This is the third and last of a series of reports of the chemical examinations required by, and made in obedience to, an act of Congress approved 3d March, 1843; the first and second of which reports are contained in Senate document No. 165, 28th Congress, 2d session, and in Senate document No. 467, 29th Congress, 1st session.

Very respectfully, your obedient servant,

R. J. WALKER,
*Secretary of the Treasury.*

Hon. Geo. M. Dallas,
*Vice President of the United States,*
*and President of the Senate.*

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Office of Weights and Measures,
*February* 27, 1847.

Sir: In the month of June, 1844, I was requested by the Treasury Department to undertake a series of investigations in relation to the chemical nature of molasses, sirups, sugars, etc., required

by an act of Congress approved 3d March, 1843, and so to conduct these inquiries as to obtain full and correct information for the guidance of the revenue officers in distinguishing sirups from molasses, and the incidental benefit of persons interested in the manufacture of sugar.

I had previously been requested, in a letter from the Hon. J. C. Spencer, then Secretary of the Treasury, of the 13th March, 1844, to prosecute such researches as might be necessary to construct an accurate hydrometer for ascertaining the proof of spirits, under the authority of an act of Congress approved 12th January, 1825, and which confers upon the Secretary of the Treasury the right "to substitute such hydrometer as he may deem best calculated to promote the public interest, in lieu of that now prescribed by law."

I therefore consented to the proposed arrangement, on condition that the department would appoint an assistant, competent to perform the chemical analyses required by these researches, under my direction, so as to enable me to prosecute the inquiries with proper rapidity, and without interference with the responsible and imperative duties devolved on me by the coast survey, and by the construction of the standard weights and measures.

The appointment of such an assistant being determined upon by the department, I nominated as a proper person Professor R. S. McCulloh, formerly professor of mathematics, natural philosophy, and chemistry, in Jefferson College, Pennsylvania; since appointed melter and refiner of the United States mint at Philadelphia.

After the appointment of Mr. McCulloh, the researches were at once commenced and prosecuted uninterruptedly by him. In devising the methods to be followed, and performing the experiments required, he constantly consulted with and was advised by me; but, in carrying out the work, much had of necessity to be left to his discretion.

The results of the investigations and experiments made by Mr. McCulloh, in so far as they relate to hydrometers, and have been reported, are given in Senate document No. 165, 28th Congress, 2d session; and upon this subject further experiments and inquiries are still to be made. On the subject of sugars, etc., two reports have already been submitted, and are published in Senate document No. 165, 28th Congress, 2d session, and in Senate document No. 467, 29th Congress, 1st session; and the third and last report is herewith communicated to the Treasury Department.

The report is divided into four chapters; the first of which contains an account of the calculations employed in the method of analyzing sugars by polarized light, simplified in application by rendering those data constant which do not depend upon specific differences of the substances analyzed; various experiments and analyses made in Cuba to determine the proportion and chemical properties of the juice of Otaheite, Creole, and Ribbon cane, and remarks showing the practical objects of such inquiries.

In the second chapter, the present state of the art of manufacturing and refining sugar both from beet and cane juice, in Europe, the West Indies, and the United States, is elaborately discussed.

The defects of the methods commonly employed for expressing the juice are pointed out, and an account is given of the various attempts which have been made in France to extract the portion of juice which is retained by the pulp when it has passed through the mill. The subject of defecation is then treated of fully, as well as the chemical reactions of the lime with the various impurities or feculencies in beet and cane juice, and the use of animal carbon for removing an excess of lime added in defecation is shown to be even more important than its decolorizing effects. The necessity of filtration is proved, and the various kinds of cloth and bone-black filters are described. Then follows a discussion of all the methods for evaporating saccharine juices hitherto tried; and after pointing out the injurious effects and the waste of the methods of evaporation in pans subjected to the direct action of the fire, or by exposing the juice to the air upon heated metallic surfaces, the advantages of evaporating by steam and in vacuo are set forth in an account of the various apparatus invented for the purpose, and in which Howard's vacuum pan, the vacuum pan of Roth, and the systems of Derosne and Rillieux are discussed. On the improvements of Rillieux particularly, which are now exciting so much interest in Louisiana, and which enable the planters to make sugar of perfect quality, full information is given. And the economy of the successive use of latent heat in trains of evaporating pans, which constitutes the chief feature of Rillieux's system, is proved by a simple calculation.

The principles of crystallization, by attending to which the planter can give to his sugar any desired size and strength of grain, are next succinctly stated, and illustrated by facts taken from the results of the present practice of sugar boilers. Attention is then directed to molasses, as a saturated solution of crystallizable sugar, and the importance of extracting this sugar is urged. This chapter ends with an article on the use of boneblack, its properties, preparation, and revivification.

The third chapter relates first to the importation of molasses, sirups, &c., and it is shown to be impossible for the revenue officers, in some cases, to decide whether an article is genuine molasses of superior quality or *sirop de batterie*, and that in such instances chemical analysis can furnish no additional information which will aid the officer. This chapter closes with facts relating to the subject of drawback on refined sugar.

The fourth chapter contains the results, arranged in tabular form, of the chemical analyses of several hundred specimens of molasses, sirup, saccharine sediments, or deposites taken from casks in which molasses was imported, and of sugars, together with the optical observations and general descriptions of those specimens, which were nearly all taken by the revenue officers, in obedience to orders from the Treasury Department.

The report concludes with an appendix explanatory of the accompanying diagrams of the various improved apparatus now used in refining or manufacturing sugar.

The information thus given, together with that contained in for-

mer reports upon these subjects, constitutes a body of knowledge which will probably be found valuable alike to the officers of the revenue, to the legislative branch of the government, and to all interested in the manufacture, the refining, or the importation of sugar.

Very respectfully, yours,

ALEX. D. BACHE,

*Superintendent of Weights and Measures, &c.*

To the Hon. ROBERT J. WALKER,

*Secretary of the Treasury.*

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PHILADELPHIA, *February* 24, 1847.

DEAR SIR: I have the honor to communicate to you the following report of investigations with reference to saccharine substances, made in obedience to an act of Congress of March 3, 1843, and which investigations have been performed by Mr. J. B. Reynolds and myself, in such manner as you have from time to time been pleased to direct, either orally or by written instructions.

In the month of August, 1845, the collectors of the ports of Boston, New York, Philadelphia, and Baltimore, were ordered to take samples, for chemical analysis, from every lot of sirup, sugar, molasses, and of sediments in molasses, which should be imported at said ports within sixty days after the reception of the order, and to transmit these samples to me at Philadelphia, with all the information requisite to identify the place of manufacture, circumstances of importation, and nature of each sample. Several hundred specimens were collected and sent to me by the revenue officers, in obedience to these instructions. They have all been carefully analyzed, and the results of the analyses, together with the observed data and descriptions of distinguishing features, or differences in color, taste, grain, &c., are now given fully in chapter 4 of this report. For the purpose of rendering evident the general facts or conclusions which are established by these numerous analyses of every variety of sugar and molasses usually met with in the markets of the United States, as well as for convenient reference, I have also arranged the results in tables 1, 2, 3, &c., of the same chapter.

Whatever may have been the design of that part of the resolution which required the question: "what quantity of sugar is contained in different saccharine substances?" to be answered by chemical investigations, the answer will, I trust, be found fully and satisfactorily given by the facts now reported.

To the examination of sirups and molasses attention has been especially paid, in consequence of suspicions entertained by some, and public statements made by others, that extensive frauds have been committed upon the revenue by the importation of pure sirups under the name of molasses. Upon this subject I have already made a partial report, which has been embodied in a communication to the Senate made by the Secretary of the Treasury, and to which

I beg leave to refer. (See Senate document No. 467, session 1st, 29th Congress.)

The further reflections now submitted in chapter 3 will, I hope, serve to enlighten legislation and the administration of the revenue laws upon these matters; and the facts therein set forth will probably be of value also to those interested in the manufacture and refining of sugar.

The method employed and chiefly relied upon in the analyses was that of M. Biot, based upon the circular polarization of light, originally described in the *Comptes Rendus des Séances* and in the *Memoires de l'Académie*, and which I have also discussed in a former preliminary report contained in Senate document No. 165, 2d session, 28th Congress. This method for the analysis of sugar has, in my opinion, the great advantage over all others of perfect accuracy, united with great facility of proper performance, so that a larger number of exact analyses may be readily made by it in a given time than by any other. Having checked it by other methods, as well as by synthetical experiments, I have not hesitated to extend to it the entire confidence which it deserves. There is something apparently so abstract, so totally different from the usual methods of evaporation, precipitation, weighing, &c., in the employment of a ray of light to determine quantities of gross matter in solution, that it seems almost too fanciful to be real. Science is full of such beautiful applications; the mariner's compass, for instance, indicating the meridian in obedience to the power of a no less ethereal agent, and which has ceased to be wondered at because it has grown familiar by common use.

The calculations required by the method of circular polarization constitute with many a serious objection to its use. They are simple, and easily made with the aid of logarithms; but, as I have desired to render this report as free from mathematical calculations as possible, as well as to avoid unreasonable length, I have not given the calculations in full of more than two or three analyses, which may serve as examples for any one who is disposed to compute from the observed data of any analysis the resulting per cent. of sugar contained; and thus to check the truth of the reported result. In justice to Mr. Reynolds, I should here state that he has repeated the calculations of all the analyses given in chapter 4, and thus endeavored to render them free from accidental errors: their general accuracy may, therefore, be confidently relied upon. After all the samples sent from the different ports had been once analyzed, many of the analyses were carefully repeated. The number thus re-analyzed was probably one-third of the whole, and comprised all which were considered in the least degree doubtful, and many which were, on the contrary, selected at random, and regarded as fully entitled to credit. The object of this repetition was to correct errors wherever they were supposed to exist, and to check work presumed to be correct. The results obtained were entirely confirmatory.

During the interval which elapsed between the time of the preparation of my first or preliminary report, and that at which I e-

ceived from the revenue officers the specimens they had collected, much of my attention was devoted to researches connected more or less directly with the subject of hydrometers. I then, in obedience to your instructions, visited the towns of Portland, in Maine; Portsmouth, in New Hampshire; Newburyport, Salem, Boston, and New Bedford, in Massachusetts; Providence, Bristol, and Newport, in Rhode Island; New Haven, in Connecticut; and the cities of New York, Philadelphia, and Baltimore; the object of these visits being partly to inspect the condition of the hydrometers used in these various ports, by comparing them with standard instruments taken with me, and belonging to the Treasury Department, as well as to ascertain the respective practices of the ports, both in proving alcoholic liquors and in gauging molasses; and partly to learn the yield of refining sugar in this country, in reference to the proper determination of the drawback to be allowed on foreign sugars refined in and exported from the United States. The information thus collected, in as far as it is relative to the question of drawback, is now given in chapter 3; but the facts which refer to the subject of hydrometers will be hereafter communicated in a separate form.

After the reception of the above-mentioned samples of sugar and molasses, &c., so large was their number that I requested and obtained permission to employ some competent chemical assistant, who might not only aid me in any operation when called upon, but also himself conduct analyses under my superintendence. In making this request, I was governed both by considerations of economy and by a desire to bring the work to as early a termination as possible. The services of Mr. J. B. Reynolds, then assistant in the laboratory of the collegiate department of the University of Pennsylvania, and previously in the magnetic observatory of the Girard College, were consequently engaged, at a very moderate rate of compensation; and it gives me great pleasure to state that I found in Mr. Reynolds a most faithful, efficient, and intelligent assistant. His practical knowledge of chemistry enabled him at once to make himself familiar with the peculiarities of the analyses, and to give him skill in their performance. I therefore felt no hesitation in recommending that the work in Philadelphia should be continued uninterruptedly by Mr. Reynolds during my contemplated journey to Louisiana and Cuba. Of the manner in which he acquitted himself of the responsible task intrusted to him, his own informal reports to you will have enabled you to judge. I will simply add that his work has been checked and confirmed by the analyses made since my return; and that so industriously did Mr. Reynolds prosecute his labors in my absence, that the larger portion of the analyses given in chapter 4 were made by him alone, and before my return.

As many saccharine substances cannot be kept long in mild climates without undergoing change by fermentation, it was, of course, impossible to base correct conclusions respecting their chemical nature and properties upon any investigations of them made after they had been subjected to the influence of a sea voyage, change of climate, &c. It was, therefore, thought necessary that these sub-

stances should be examined in the places of their production; and to that end, that I should go both to Louisiana and Cuba. The alleged frauds upon the revenue, the conflicting views and statements of persons professing a full knowledge of facts, and the important interests connected with and dependent upon the manufacture of sugar, constituted reasons which, if there had been no other, would have required the journey to be undertaken. So comprehensive and indefinite is, however, the act of Congress instituting these inquiries, that the instructions I received were of necessity very general, and left much to my own discretion. If, therefore, in endeavoring to comply with and carry them out in their spirit, by directing my attention chiefly to those matters which appeared to me most important, either to the government or to the sugar industry of our country, I have erred in judgment in any matter, the error will, I trust, be deemed one that could not readily have been guarded against.

I am fully conscious of the imperfections of that portion of my report which is contained in chapters 1 and 2, and which is designed to furnish information to planters, refiners, and others, respecting the chemical nature and the proper mode of the manufacture of cane sugar. But such as it is, it will, I hope, be found to contain only views based upon correct scientific principles, and therefore be useful to many who are apt to be misled by erroneous statements.

In anticipation of my journey to the south, and in obedience to your orders, I had collected together, and caused to be carefully and compactly packed in boxes, such apparatus as would be necessary for the proper performance of any analyses I might find it requisite to make either in Louisiana or Cuba. Notwithstanding all my efforts to reduce the bulk of such apparatus, it filled several boxes. This proved a source of serious incumbrance; for by reason of the unusual and early severity of the winter, the Ohio river became firmly frozen on the very day I reached it on my way to New Orleans, the 5th of December, 1845, and remained so during the whole of that month, and until I finally retraced my steps at the beginning of January. Had my baggage consisted only of my wearing apparel, I might have gone by land to Memphis, Tennessee, and thence by the Mississippi to New Orleans. But such a journey became impracticable, in consequence of the apparatus I was obliged to carry with me; and I had therefore no alternative but to return, or wait until the navigation of the river should open. I had already been induced by the probability of the occurrence of milder weather, and of a thaw, to linger upon the Ohio until I felt at liberty to wait no longer; and having written for instructions, which, though sent, failed to reach me, I determined to return to Washington, and act in obedience to such orders as might there be given me. The time had passed in which I could, with any reasonable expectation, seek to arrive in Louisiana during the sugar-making season; and the gathering of the Cuba crop had commenced. Under these circumstances, the Secretary of the Treasury saw fit to direct that I should go to New York, and thence proceed to Cuba with as

little delay as practicable. I accordingly went at once to New York and engaged my passage in the Havana packet which sailed on the 10th January, but my apparatus did not arrive in time; it had been detained in consequence of deep snows among the mountains, over which it was conveyed by wagon. No other vessel was expected to sail directly for Cuba within a month; I therefore sought the advice of merchants engaged in the Cuba trade, who recommended that I should sail either to Charleston or New Orleans, and and there take passage for Havana in one of the vessels constantly engaged in carrying rice or other provisions. I preferred to go by way of New Orleans, because, though less direct, I could, if detained, occupy myself advantageously in examining the Louisiana sugar industry. In making this choice, I have reason to believe that I acted wisely; for though I did not reach New Orleans before the close of the grinding season, I yet found the short stay I was obliged to make there of great value, by reason of the information it enabled me to obtain. I would gladly have protracted my visit to Louisiana, and my study of its sugar interests, but I felt bound, in obedience to my orders, and in consideration of the rapidly approaching termination of the grinding season in Cuba, to hasten my departure, and therefore took passage in the first vessel which sailed for Havana.

In consequence of letters which I took to the commercial house of Drake Brothers & Co., and which were politely given to me by Moses Taylor, esq., an eminent merchant of the city of New York, I enjoyed every facility I could desire for the prosecution of my researches in Cuba. Having ascertained that there were no large sugar estates in the immediate vicinity of the city of Havana, I went first by railroad to San Julian de los Guines, a town of 2,500 inhabitants, about forty-fives miles from Havana and ten miles from the sea, on the south side of the island. The principal objects I proposed to attain by this trip, were, first, to examine cursorily the plantations in the neighborhood of Guines, and particularly the *Ingenio Amistad*, a sugar estate, upon which a Derosne train was in successful operation; and, secondly, to observe the transverse geological section of the island, so that I might form some conception of the nature of its various soils.

Guines is situated in a large and perfectly level plain, comprising an area of about 200 square miles, and extending on the south quite to the sea, while on the other three sides it is hemmed in by distant and bold mountains. This plain rests upon a *chalk formation*; and being well watered by numerous and beautiful rivers, it constitutes one of the most fertile districts in the island.

Here are seen large coffee estates, divided by avenues of royal palms, of cocoas, and of mangoes, into numerous and regular squares, in which the coffee tree and the banana are densely planted in alternate rows, and around which the orange, the lime, and the lemon, the pomegranate and the rose apple, form a border loaded with delicious fruits, and constantly ornamented with fragrant and beautiful flowers; while along the avenues rows of pine apples line the carefully graded walks, in which no blade of grass is permitted to grow, nd stone walls, upon which the r'ght blooming ceres

creeps and thrives in the intense light and heat of the solar rays, or hedges of aloes, whose spear-like leaves effectually prevent intrusion from man or beast, enclose the whole. In the very centre of such a paradise as this, often including two or three hundred acres, the coffee planter erects his dwelling and finds his home.

Here, also, boldly contrasted with the quiet and studied beauty of the neighboring coffee estate, appears the sugar plantation, in its utter plainness. Large fields of luxuriant cane stretch far and wide; the monotony of the landscape being broken only by a few scattered royal palm trees, rising perpendicularly to the height of fifty or sixty feet, and then spreading out their long feathery leaves in a stately crest; and by the immense buildings used for the manufacture of the sugar, above the roofs of which rise the high chimneys of the furnaces, emitting dense volumes of black smoke, and indicating that the steam engine and the spirit of commercial enterprise are busily at work. No avenues or groves adorn the premises, not even about the mansion of the proprietor, which is usually extremely plain and placed in the very midst of his other buildings, more as an office for business than as a pleasant abode; the whole establishment, indeed, often serving the purpose rather of an immense factory than of a country residence for the wealthy owner and his family, who not unfrequently spend their time in the cities.

Neither the coffee nor the sugar estates of the plain of Guinea are, however, more interesting than the luxuriant growth of its native forests. Immense cedars, with trunks six feet in diameter and fifty feet in length, are mingled with lofty palms, the huge ceyba, the valuable mahogany, the ebony, and the lignumvitæ; while the wild orange, various small trees, innumerable vines, and parasites or air plants of a thousand different species, form an undergrowth, too dense for any but the smallest animals to enter. Here the chemist may see illustrated, on a grand scale, the truth that plants derive their nourishment chiefly from the atmosphere; for here the struggle is not for soil, in which roots may be firmly and deeply fastened, but for a few inches of open sky, through which to catch a portion of air and of life-giving solar light—a struggle in which the parasites seem to have greatly the advantage, fastening themselves upon and finally crushing, as they do, even the strongest tree that upholds them. Of all these parasites none is more powerful and singular than the *ficus indica*, the Indian rubber tree. Attaching itself first as an air plant, in the form of a feeble vine, to the lofty branch of some gigantic tree, it grows downwards, dividing, as it falls, into numerous branches: these branches reach the ground and take root, and each becomes the attachment of a separate trunk; all united, however, above in one common stem. The plant then grows rapidly, increasing greatly in thickness, and sending off from each trunk, laterally and upwards, branches which entwine about the parent tree. Soon each interwoven stem and branch of the parasite attains a size varying in diameter from four or five inches to a foot; and the lordly tree, which had often proudly withstood the tropical hurricane, and which had at first generously supported

the delicate vine, now becomes its prey, and decays within its deadly and crushing embrace.

With no fact was I more struck, during the whole of my stay in the island, than with the vigor of vegetable life, and its dependence rather upon the agency of heat and light than of mere soil. The theory of the growth of plants, which has been the result of such detailed experiments and labored arguments among northern chemists, here forces itself at once on the mind, and compels conviction through the medium of the senses. Who that sees parasites growing upon every tree, dead or alive, whether the wood thereof be soft or spongy, or hard as iron; whether it be green and abounding in sap, or dry and seasoned; and the cactus flourishing beneath a vertical sun upon the surfaces of naked rocks, can persuade himself that *soil* is indispensable to vegetable growth?

The preceding observations, whatever value they may have in their general scientific bearing, have, however, a relation more closely pertaining to the subjects of this report, inasmuch as they present the grounds upon which I base the opinion I entertain, that whatever advantages the rich diluvial soil of Louisiana may possess, these are more than counterbalanced by the increased vigor of vegetable life upon lands in Cuba even of much inferior quality.

At Guines I found no difficulty in hiring good horses, it being a place much frequented by strangers, and particularly by consumptive invalids from the United States. With no other guides than some of my suffering fellow-countrymen, who, in their daily exercise on horseback, had grown familiar with the various roads, I passed from one estate to another, without a single letter of introduction to commend me to attention, yet everywhere received with perfect politeness, and with that generous and easy hospitality which distinguishes the native population of Cuba, no less than the planters of our own country.

Thus I spent my time at Guines, and returned to Havana after an absence of but three days. I had fully accomplished the objects of my visit, having made a rapid though careful *reconnoissance* of the industry, the vegetation, and the geology of a large section of the island. From what I had seen, I had obtained information which enabled me to form a more definite plan for the prosecution of my investigations; and the well managed sugar estates (furnished with costly machinery) which I visited, and which had each required, on an average, an investment of not less than a hundred thousand dollars in fixed capital, had entirely dispelled from my mind all preconceived notions derogatory to the enterprise and intelligence of the Spanish Creole.

The planters of Cuba, whether we judge them by the progress made in improvements, by the skill exercised in the operations of manufacture, by the judicious management of their estates, or by the information and intelligence they display, may certainly be considered as the equals of our own fellow-citizens; and should this island ever become free, her prosperity will perhaps exceed that of any equal extent of territory in North America; for nature

has blessed her with a climate and a degree of fertility unsurpassed by those of any part of the globe.

Leaving Havana immediately after my return from Guines, I proceeded to Matanzas, and went directly out to the large sugar estates in the country south of that port, to which my attention had been particularly directed by the honorable R. J. Walker, Secretary of the Treasury. Letters had been politely given me by Mr. Brinkerhoff, of the house of Drake Brothers & Co., to James Macomb, esq., proprietor of the *Ingenio Victoria*, near Limonar, and to Jno. Duggan, esq., of the *Ingenio Saratoga*, a large estate belonging to the above-mentioned commercial house. Under the hospitable roof of Mr. Macomb I was most politely welcomed, and enjoyed for several days every facility for the careful observation of the method employed in the manufacture of muscovado sugar.

From this plantation I went next to the Saratoga estate, where Mr. Duggan received me most cordially, and invited me not only to make his house my home during the rest of my stay in the island, but also to permit him to send to Matanzas (25 miles distant) for my apparatus, and to prosecute my chemical researches with his assistance, and under his notice. A room was tendered to me for the purpose, and I was assured that my acceptance of it would be a source of real gratification. At first I was disposed to decline this most desirable offer, supposing it to have been prompted by the extreme politeness and hospitality of Mr. Duggan, and feeling unwilling to trespass upon his generosity. But the invitation was urged in such a manner as to convince me that he sincerely desired me to do as he had requested, and I therefore cheerfully acquiesced in the proposed arrangement. My previous plan was to have returned to Matanzas after visiting the Saratoga and other estates, and to have sought out some convenient and accessible office in which to make analyses of cane juice and other substances procured from the nearest estates. By this new arrangement I was not only relieved from further trouble and uncertainty, but enabled to avail myself of facilities which could have been commanded in no other way. At any moment I could obtain the cane juice perfectly fresh, and at all stages of the process of manufacture, as well as the canes themselves, and every other interesting product. Here, also, under the instruction of my experienced and intelligent host, I could study quietly and carefully all the details incident to the manufacture of clayed sugar, and under his guidance visit and compare the operations on all the neighboring estates. The *arriero*, with a number of pack mules, was therefore despatched to Matanzas for the apparatus I had left there in the charge of the American consul; and upon its arrival, I found myself in the possession of every facility, and of a laboratory as well furnished and convenient for analytical researches as any chemist could desire.

Upon the Saratoga estate I consequently performed my analyses, and remained until, my proposed work being finished, I was ready to return to the United States. The time had passed rapidly while

I was thus engaged, and it was not until the month of April that I found myself again in Havana and on my way to New Orleans.

In Louisiana I remained but a few days, occupying myself chiefly with inquiries concerning Rillieux's improved method, and an examination of his apparatus, upon the plantation of Messrs. Packwood and Benjamin, to whose politeness I am indebted for much valuable information.

Since my return to the north, many substances have been analyzed which I brought with me from Cuba; for I there examined only such things as were likely to change by fermentation, reserving all that could be brought away without injury for future and more convenient investigation.

The results of these inquiries will be found in chapters 1, 2, and 4. That they have constituted a work of much labor will be apparent. It has been executed and reported with as little delay as possible; but with what success or practical value, I must leave to yourself and others to judge.

In all my investigations I have constantly endeavored to keep in view the fact that they were designed not to extend general or speculative chemistry, so much as to arrive at practical and economical results. In theoretical chemistry exact combinations and reactions are the legitimate subjects of pursuit and inquiry; but in chemistry applied to the arts, considerations of mechanical construction, time, labor, or expense, often render impracticable that which would otherwise be most easy and simple, and become, therefore, subjects of the first importance.

I have not seen fit to include the culture of the cane among the matters discussed in this report. It has heretofore been far better understood by the planter than the manufacture of sugar from the juice; yet the analyses I have made of the ashes of the cane, and of some other substances, relate more particularly to this subject, and I may hereafter state the conclusions they tend to establish, but which at present I consider too speculative for practical and industrial purposes.

Respectfully submitted by your obedient servant,

RICHARD S. McCULLOH.

To Professor A. D. Bache.

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# REPORT

*To Professor A. D. Bache of investigations made under his superintendence by Professor R. S. McCulloh, in relation to sugar and its manufacture.*

## CHAPTER I.

### ANALYSES AND EXPERIMENTS ON THE SUGAR CANE, MADE ON THE INGENIO SARATOGA, IN CUBA.

To any one who possesses a general knowledge of chemistry, the investigations reported in the various articles of this chapter will, I hope, be found readily intelligible, and the reasons which dictated each particular experiment will also be manifest, either from its bearing upon some practical point, or upon the chemical theory of the extraction of sugar from cane juice.

To such information as may be found in almost any elementary treatise on chemistry, it is, however, necessary to add the following:

1. *Cerosie* is a substance closely resembling beeswax, both in its appearance and its properties. It was discovered or first investigated by M. Avequin, of New Orleans, who gave it the above name. A more full account of it, taken from M. Avequin's description, is given in the treatises on chemistry both of Liebig and Dumas,* to which I therefore refer. The planter may, however, for all his purposes, regard it as wax.

2. *Pectine, pectous* and *pectic acid, metapectine, metapectous* and *metapectic* acid, are terms used very loosely, it is to be feared, by chemists. They appear to be applied in common to very distinct substances, and the analyses even of one kind of pectine or pectic acid made by equally skilful chemists do not agree. In the following analyses I use the term *pectine* to denote a mucilaginous substance contained in the cane, soluble in hot water, but insoluble both in alcohol and cold water. And by *pectic acid* I designate the analogous substance, which is precipitated by sub-acetate of lead and other re-agents in the form of a viscid or mucilaginous compound or salt. It is very desirable that this whole subject of pectine should undergo revision by some chemist of ability and skill. It was my intention to have devoted particular attention to the mucilage stated to be contained in Louisiana cane juice, often in quantities so large as to give great trouble to the sugar boilers;

*Dumas Traitè de Chim., vol. 6, p. 699; Paris, 1843. Also Liebig's Chimie Organique, vol. 2, p. 304; Paris, 1844.

and I regretted the circumstances which impeded my journey thither more on that account than any other; but I now attach less importance to the subject, for it has been shown by Messrs. Benjamin and Packwood and by others that the use of boneblack and of evaporation in vacuo give perfect results. Some planters had, I am told, entertained the opinion before that boneblack could not be used for purifying the cane juice of Louisiana; an opinion, doubtless, based upon unskilful experiments.

3. The distinction between cane or crystallizable sugar and uncrystallizable sugar is one obvious enough for practical purposes, and which I have discussed somewhat fully in a former report, to which I therefore refer, (See Senate document No. 165, 2d session, 28th Congress.) For examining a solution of these different sugars, the copper test of Trommer (described also in the above mentioned report) is employed, and it possesses extreme delicacy, giving a rich blue color, with pure solutions of crystallizable sugar, and a dense red precipitate, if the smallest quantity of uncrystallizable sugar be present.

4. The optical phenomena presented when a ray of polarized light passes through a saccharine solution furnish the readiest, most searching, and most exact method of determining not only the nature but the quantity of crystallizable sugar in any saccharine substance.* M. Barreswill has brought forward a method of analysis founded upon the above reaction of sugars with the copper test, which cannot, in my opinion, be compared, either for accuracy or convenience, to the optical method; and it is preferred only by those who have not familiarized themselves with the advantages and manipulations of the latter.

Although I have already given in detail all the formulæ for calculation, and explained fully the principles upon which the method of analyzing sugars by circularly polarized light is founded, to which I may therefore refer for full information, (Senate document No. 165, 28th Congress,) as well as to the researches of M. Biot, in the *Mémoires de l'Académie* and the *Comptes Rendus des Séances de l'Académie*, yet, as in calculating the results, and in performing the analyses now reported, many simplifications are introduced by the artifice of rendering constant such quantities as did not require to be variable by reason of their constituting specific differences of the substances examined, I deem it proper to present the simplified formulæ, even at the expense of causing the rest of these introductory remarks to be repulsive to some by reason of an algebraical dress.

The law of circular polarization by liquids discovered by M. Biot—that *the angle of deviation for any homogeneous ray is proportional to the length of the tube, the density of the liquid, and the proportion of active matter*—gives the following formula:

$$a = l\ d\ e\ x\ (a) \qquad (1.)$$

* See Appendix, note A.

In which $a$ denotes the total angle of deviation; $(a)$ the molecular rotary power, or unit of angular deviation; $l$ the length of the tube; $d$ the observed density or specific gravity; $e$ the proportion or per cent. of the substance dissolved and to be analyzed; and $x$ the unknown per cent. or proportion of active matter in that substance.

If the substance to be analyzed consists of a mixture of cane sugar and other active substances, then will the angle of deviation observed in a solution of definite proportions be expressed by

$$a = S + D; \qquad (2.)$$

S denoting the effect produced by the cane sugar, and D that by other substances; and if this solution be diluted to the strength denoted by $n$, we shall have

$$n\,a = n\,S + n\,D; \text{ or, } a' = S' + D' \qquad (3.)$$

Putting

$$a' = n\,a, \text{ etc.}$$

Lastly, if the substance employed for diluting be an aqueous solution of hydrochloric acid, it will exert a peculiar chemical and optical change on the crystallizable sugar only, by converting it into a substance for which the angle of deviation changes its sign, or which is *left polarizing;* and if this diluted and *inverted* liquid be observed, we have

$$a'' = D' - r'\,S' = -\,r''\,a' \qquad (4.)$$

In which equation $r'$ denotes the ratio of the inverted to the direct angle of deviation for pure crystallizable sugar; and $r''$ the corresponding ratio of inversion for the substance to be analyzed.

From equations (3) and (4) we get

$$S' = \frac{1 + r''}{1 + r'}\,a' \qquad (5.)$$

From equation (1) we have

$$(a) = \frac{S}{l\,d\,e\,x} = \frac{S'}{n\,l\,d\,e\,x} \qquad (6.)$$

In these equations, $r'$ and $(a)$ are constants depending upon the chemical nature of cane sugar; the value of $r'$ has been carefully determined by M. Biot to be 0.38; and $(a)$ may be eliminated as follows:

For a 25 per cent. solution of the sugar used as the standard of these researches, observation gave

$$(a) = \frac{S'}{n\,l\,d\,e\,x} = \frac{42°.5}{l\,d\,e};$$

$x$ and $n$ being each unity, $d$ was found to be 1.1056; and $e$ being 0.25, we have

$$l\,(a) = \frac{42.5}{(0.25)\ (1.1056)} = 153.76$$

Hence, by substituting in equation (6,) we have

$$x = \frac{S'}{153.76\ n\ e\ d} \qquad (7.)$$

And using for $n$ and $e$ in the analyses the constant values 0.9 and 0.25, we have, by substitution and reduction,

$$x = \frac{S'}{34.596\ d} \qquad (8.)$$

Which, with formula (5,) was that usually employed in the calculations. The corresponding logarithmic equations are

$$\left.\begin{array}{l} \log.\ S' = \log.\ a' + \log.\ (1 + r'') - \log.\ (1 + r'); \\ \text{And } \log.\ x = \log.\ S' - \log.\ d - \log.\ (34.596); \end{array}\right\} \quad (9.)$$

in which $a'$, $r''$, and $d$, simple functions of the observed data, are the only variables.

That these expressions may be simply and easily calculated numerically will be evident from the examples worked out in this chapter, and which may also serve to illustrate the calculations required for each analysis of chapter 4; the observed data of which are there all given, and the results also arranged in tabular form.

*Experiments on the behaviour of Otaheite cane juice with chemical re-agents.*

5. This cane juice was perfectly fresh, of a greenish brown color, somewhat turbid, and of the specific gravity 1.07 at 77° Fahrenheit, the temperature of the room; or 9° Beaumé, *pèse-sirop*, as indicated by the instrument I employed. It had the peculiar stiptic taste of the rind and leaves of the plant.

Treated with a solution of caustic baryta it became more decidedly green, and, after standing a few moments, gave a flocculent precipitate; the supernatant liquid being perfectly transparent, and of a yellowish green color.

Both powdered lime and lime water gave bulky precipitates and clarified the juice.

A solution of caustic potash changed the color of the juice to yellowish green, or greenish yellow; but instead of separating,

seemed rather to dissolve more completely the feculencies. Heat produced no effect on this mixture, except to deepen the color, but after standing three or four hours the feculencies were imperfectly precipitated.

Carbonate of potash changed the color to reddish green; and when heated, the mixture did not clarify; nor did the feculencies appear to separate, except by evaporation from the protracted application of heat, and not by any chemical action.

Carbonate of ammonia changed the color of the juice to a dark greenish brown, and did not clarify it at all, even after a repose of several hours.

With a solution of bichloride of mercury, (corrosive sublimate,) a white flocculent precipitate subsided, and a dirty scum rose to the top, the intervening liquid being perfectly transparent and colorless.

Sulphate of zinc gave no precipitate when cold; but with the aid of heat, a scum rose, which, by continued application of heat, separated from air bubbles and subsided as a slight precipitate.

A solution of tannin gave a small precipitate; and after filtration, the juice was nearly clear and colorless.

With an alcoholic solution of iodine, this cane juice gave no reaction, and not the slightest change of color. Hence I conclude that free starch cannot exist in it.

Filtered through coarse boneblack, the color was entirely removed, but the liquid remained opalescent, in which, with the copper test of Trommer, not even a trace of uncrystallizable sugar was found to be present.

Heat alone caused a scum to rise to the top, which adhered to the vessel. This scum was insoluble both in water and alcohol. The filtered liquid was perfectly transparent, but of a green color. With baryta, it gave a flocculent precipitate.

Heated with fine boneblack and filtered, it lost its color entirely, but was not clear; and when treated with a solution of caustic baryta, this filtered juice grew turbid; nor did it clear when heated, which only caused it to become dark colored. The reaction with lime water was similar to that with baryta.

With a solution of the sub-acetate of lead, this cane juice gave a flocculent light olive colored precipitate, and the supernatant liquor was clear and colorless, the cane juice itself from which it was formed being even of a much darker color than the precipitate.

Sub-acetate of lead being employed in excess, the supernatant clarified juice was decanted and filtered through coarse boneblack, which rendered it perfectly limpid and colorless. In this filtered juice neither iodide of potassium, sulphuric acid, nor hydrosulphate of ammonia, gave the slightest indication of the presence of lead; which seems, therefore, to be separated by boneblack. Nor could the slightest trace of uncrystallizable sugar be detected in it by the copper test of Trommer.

The precipitate formed as above, by sub-acetate of lead, could not be separated by filtration. It was so viscid as to clog the

pores of the paper; and after standing twelve hours, the supernatant liquid still continued to occupy the filter. When this liquid was poured off, the precipitate which coated the filter was of a mucilaginous consistence. Dried on wire gauze over a lamp, and allowed afterwards to stand, it grew moist, and is, therefore, deliquescent.

This precipitate with sub-acetate of lead was insoluble in water or alcohol, both cold and boiling; sparingly soluble in sulphuric ether, which becomes colored and leaves a resinous film when evaporated. Concentrated hydrochloric acid, with the aid of heat, dissolves it partially. So likewise does a solution of caustic potash, which becomes dark colored. Hydrochloric acid renders the potash solution colorless and opalescent, but gives no precipitate; nor does the bichloride of mercury give a precipitate with either the potash or the acid solution.

*Comparative experiments on the yield in juice of the three varieties of cane.*

6. I weighed out accurately 21.111 ounces of Ribbon cane, which was then rolled in a hand mill, consisting of a pair of small rolls similar to those used for rolling metals, or to the large rolls of the ordinary sugar mill. For the use of this apparatus I was indebted to Mr. Duggan, of the Saratoga estate, who had caused it to be constructed for similar experimental purposes. The above-mentioned quantity of cane thus yielded 12.542 ounces of juice, of the specific gravity 1.085, corresponding to 10° Beaumé of the brass instrument I employed, but to 11° Beaumé as indicated by the glass *pèse-sirop* belonging to Mr. Duggan. The wet begassa obtained at the same time weighed 8.007 ounces.

The sum of the weights of the juice and the begassa being only 20.549 ounces, it follows that 0.562 is the weight of juice lost and retained upon the surface of the mill. This loss I considered so great that I was induced to repeat the experiment with, if possible, greater care, and with the following results: 19.483 of ribbon cane yielded 11.024 ounces of juice, and 7.886 ounces of moist begassa, the quantity of juice retained by the mill or lost being 0.573 ounce. Hence we have the comparative results:

| | First experiment. | Second experiment. |
|---|---|---|
| Moist begassa | 37.92 | 40.51 |
| Juice obtained | 59.40 | 56.58 |
| Juice lost | 2.68 | 2.91 |
| Ribbon cane | 100.00 | 100.00 |

7. After drying for forty-eight hours by exposure to air and sun, the 8.007 ounces of moist begassa of the first experiment weighed only 3.422 ounces, and had therefore lost 4.585 ounces of water by evaporation. So likewise the 7.886 ounces of begassa of the second experiment, similarly dried, weighed 3.510 ounces, and had therefore lost by evaporation 4.376 ounces of water. If this

water be supposed to be united with one fourth of its own weight of sugar—a supposition which probably differs little from the truth —then 5.731 would be the amount of juice retained by the 8.007 ounces of moist begassa in the first experiment, and 5.470 ounces would be the corresponding amount of juice retained by the moist begassa of the second experiment. Hence it would follow that the ribbon cane experimented upon consists of:

| | By 1st experiment. | By 2d experiment |
|---|---|---|
| Woody fibre | 11.00 | 12 40 |
| Saccharine juice | 89.00 | 87.60 |
| | 100.00 | 100.00 |

Of the 88 per cent. of juice thus shown to exist in this ribbon cane, 62 per cent. only were expressed, and the begassa of cane ground in large mills probably retains a similar proportion.

8. From 15.072 ounces of Creole or crystallina cane, rolled in the same manner as the above 9.399 ounces of juice of the specific gravity 1.079, or 9°.5 Beaumé, were obtained, and also 5.365 of moist begassa; 0.308 ounce of juice being left on the surface of the rolls. By drying for forty-eight hours in the air and sun, the 5.365 ounces of moist begassa lost 2.666 ounces of water; and supposing this water to have existed in that begassa as saccharine juice, containing about one-fifth of sugar, we have as the yield by rolling, and the composition of this cane, the two following respective results:

| | | | |
|---|---|---|---|
| Juice expressed | 64.40 | Juice contained | 86.50 |
| Moist begassa | 35.60 | Dry woody fibre | 13.50, |
| | 100.00 | | 100.00 |

Hence we find that only about three-fourths of the juice contained in this cane was expressed by the process employed.

9. By similar treatment 10.3855 ounces of Otaheite cane yielded 6.502 ounces of juice of lighter color, apparently cleaner than that obtained from either of the other varieties of cane, and of the specific gravity 1.0875, or 10°.5 Beaumé; also, 3.652 ounces of moist begassa. It had, therefore, left on the surface of the rolls of the mill 0.2315 ounce of juice. After drying the begassa for two days in the sun, it weighed 1.9202 ounce, and had, therefore, suffered a loss of 1.7318 ounce of evaporated water. Hence I deduce, as above, the results:

| | | | |
|---|---|---|---|
| Juice expressed | 64.83 | Juice contained | 85.67 |
| Moist begassa | 35.17 | Woody fibre | 14.33 |
| | 100.00 | | 100.00 |

The begassa, therefore, retained 20.84 per cent. of the 85.67 per cent. of juice which this cane contained.

The crystallina cane employed in the preceding experiments was *plant cane*, while the ribbon and Otaheite were *rattoons:* hence the great difference of density in the juice obtained from the former. A perfectly fair comparison of the three varieties could only be made by using either plant canes or rattoons for each; but these experiments serve to show, also, that juice from plant canes is of inferior richness to that from rattoons. In other respects the canes were similar, and the comparison exact, for they had all grown in the same field, and were of the same age.

10. To ascertain whether the feculencies which are contained in cane juice, and which it is requisite to separate in the process of manufacture, do not come principally from the rind of the cane, I peeled off this rind from several pieces of Otaheite cane, and ground the inside pith by itself; the juice from which was not only of much lighter color than that from the same cane ground with its rind on, but also gave a far smaller precipitate with sub-acetate of lead and other re-agents.

*Analysis of Otaheite cane juice.*

11. Five ounces of fresh cane juice, just from the mill, of the specific gravity 9° Beaumé, were weighed exactly, and to this one ounce of a solution of sub-acetate of lead was added, which caused an abundant precipitate to take place. After standing one hour to settle, the clear supernatant liquid was decanted carefully, and alcohol poured upon the precipitate, that it might be filtered. The filtration was performed readily, and the filtered alcoholic liquid was of a beautiful transparent yellowish green color, indicating that the alcohol had dissolved some coloring matter. With iodide of potasssium this filtered liquid gave an abundant precipitate of iodide of lead, showing that the sub-acetate of lead had been used in excess. The washed precipitate, dried over a lamp on wire gauze, was found to weigh 0.049 ounce; and, when incinerated in a porcelain crucible, it yielded 0.0206 ounce of protoxide of lead. Hence five ounces of this cane juice give with sub-acetate of lead a precipitate containing 0.0284 ounce of extractive matter; which amounts to 0.568 ounce in 100, or rather more than half of one per cent.

12. Of the same kind of cane juice, specific gravity 1.0843, one hundred volumes were mixed with three volumes of a solution of sub-acetate of lead, and the mixture was then filtered. After filtration the liquid remained opalescent and of an olive tint, and sub-acetate of lead gave with it a slight mucilaginous precipitate, which floated instead of subsiding, showing the saturation incomplete. Neither iodide of potassium nor sulphuric acid could detect in it a trace of lead. Filtered through fine boneblack, with which it had previously been gently heated, it became colorless and sufficiently transparent for

optical examination, to which it was then subjected with the following results:

$d = 1.075$; $t = 27.6$ C
$a = 29°$ ; $e = 0.97$
$a'' = -9°.5$ ; $n = 0.9$

Hence,

| | | | |
|---|---|---|---|
| log. $a$ | 1.46240 | log. $(1 + r'')$ | 0.13481 |
| log. $n$ | $\bar{1}$.95424 | log. $a'$ | 1.41664 |
| log. $a'$ | 1.41664 | log. $(1 + r')$ a. c. | $\bar{1}$.86012 |
| log. $a''$ | 0.97772 | log. S | 1.41157 |
| log. $r''$ | $\bar{1}$.56108 | | |

$$x = \frac{S}{132.79d}$$

Hence,

| | |
|---|---|
| log. (132.79) | 2.12316 |
| log. $d$ | 0.03141 |
| | 2.15457 |
| log. S | 1.41157 |
| log. $x$ | $\bar{1}$.25700 |

Therefore $x = 0.1807$. And hence this cane juice contains 18.07 per cent. of crystallizable sugar.

We may therefore regard the juice examined as composed of:

| | |
|---|---|
| Water | 81.36 |
| Crystallizable sugar | 18.07 |
| Extractive matter | 0.57 |
| | 100.00 |

The preceding calculations, in which the log. $a'$ exceeds slightly log S, would indicate a trace of some other right polarizing substance besides cane sugar; but, as these numbers differ only in the third place of decimals, the variation is within the limits of errors of observation. With Trommer's copper test I obtained only the blue color for cane sugar, and no reduced oxide of copper. Hence I conclude that ripe cane juice, when fresh, contains only crystallizable sugar.

13. To confirm the above results of optical analysis, I placed in a porcelain crucible, weighing 0.572 oz., a portion of the same cane juice, which weighed, together with the crucible, 1.56725 oz. Hence 0.99525 was the weight of the juice. This juice was then gently evaporated over a spirit-lamp to a thick sirup. After which, it was placed in the oven used for drying the clayed sugar, and allowed to remain there twenty-four hours, when it was taken out and found to be quite solid and dry. To expel any remaining moisture, I again heated it gently over a spirit-lamp, and then weighed it; the weight of the crucible and its contents was 0.75816 oz. And therefore 0.99525 oz. of juice yielded 0.18616 of dry solid matter. Hence we have as the composition of this cane juice:

| | |
|---|---|
| Water | 81.3 |
| Solid matter | 18.7 |
| | 100.0 |

A result which agrees perfectly with that obtained optically, and which this experiment was designed to test, by a ruder but less abstract method; but which result differs somewhat from that obtained by MM. Péligot and Casaseca, who give 79 per cent. of water and 21 per cent. of sugar as the composition of Otaheite and Creole cane juice.*

It should here be stated that, at the time when the analysis I have just given was performed, the yield of the cane, in this part of the island, was unusually deficient; on the Ingenio Victoria, for instance, 15 cart loads of cane were required to produce a hogshead of muscovado sugar; whereas 10 cart loads only would ordinarily have been necessary. This circumstance was ascribed by Mr. Macomb to the influence of rains, which had recently fallen. An explanation which, in my opinion, is both entitled to consideration, and highly probable; not only because it was offered by a gentleman of great intelligence and practical experience, who must have been accustomed to observe the consequences of such events attentively; but also, because the same cause is known to produce like effects upon beet juice. The density of which often varies to the extent of one or two degrees in the course of a few days; so that beets from the same field, which yielded, for instance, juice of 9° Beaumé during dry weather, will, after a rain, furnish juice of 7° only.

For the reasons just mentioned, it is probable that 21 per cent., as obtained by MM. Péligot and Casaseca, may be the usual or average proportion of sugar in ripe cane juice, rather than 18 per cent., as given above by my analysis of a particular and perhaps unfavorable specimen.

14. The dried solid matter of the preceding article was placed in a glass tube, which was then drawn out with the lamp and nearly

*Ann. de Chim. et de Phys., t. xi, p. 39. Also, see notes B, C, and D, of the Appendix.

closed. The contents was subjected to dry distillation to detect nitrogenous substances. The strong odor of caramel rendered the sense of smell insensible to feeble traces of other matters, but hydrochloric acid vapor gave not the slightest indication of ammonia.

*Analysis of the juice contained in different parts of the same cane.*

The canes used in these experiments were of two varieties: Otaheite of about nine months growth, and crystallina of seven months.

15. Of the Otaheite cane, the three or four top joints, enveloped entirely in leaves, had a sour astringent taste, and promptly stained the knife black with which they were cut. Expressed between iron rollers, the juice obtained was blackened by the metal, and in quantity was insufficient for taking its specific gravity. The copper test of Trommer yielded a copious pecipitate of protoxide of copper; and the tincture of iodine gave no indication of starch.

16. Three or four joints taken from the same cane as the above, and immediately below them, gave a juice of the density of 7° Beaumé, and of a slightly sweet astringent and acid taste. With this juice, sub-acetate ef lead gave a dense dark olive pecipitate, in bulk equal to four-fifths of the entire volume of the mixture. So also with the juice obtained from the top joints, sub-acetate of lead gave a precipitate similar both in color and quantity. With the copper test a precipitate took place of reduced oxide of copper, and tincture of iodine gave no reaction.

A quantity of this juice, being clarified with sub-acetate of lead, and the excess of lead thrown down with bi-carbonate of soda, was subjected to optical analysis and with the following data:

$$d = 1.051;\ t = 21°.5\ C$$
$$a = 10°\ ;\ e = 0.545$$
$$a'' = -3°.5\ ;\ n = 0.9$$

Hence, by calculation, $x = 0.1041$; and therefore this juice contains 10.4 per cent. nearly of cane sugar.

The equation $a = S + D$ gives with the above data a negative value for D, indicating the presence of a substance possessing the property of left polarization, and which, therefore, is most probably uncrystallizable sugar.

17. Three or four joints taken from the bottom of the same cane as the above yielded a juice of the specific gravity of 10°.5 Beaumé, and perfectly sweet in taste. With this juice the copper test gave not a trace of reduced oxide of copper, but the transparent characteristic blue color obtained from crystallizable sugar. And sub-acetate of lead gave a light olive colored precipitate in quantity much less than the similar precipitates of the above experiments, being only in bulk about one-half of the volume of the mixture; nor was it as dense as those precipitates.

Subjected to optical analysis in precisely the same manner as the juice of the upper joints, I obtained from it the data:

$$d = 1.070;\ t = 21°.3\ C$$
$$a = 20°\ ;\ e = 0.545$$
$$a'' = -5°.75;\ n = 0.6$$

Hence, by calculation, $x = 0.1942$; and therefore this juice contains 19.4 per cent. nearly of crystallizable sugar. From these data we obtain for D a positive, but extremely small value; so that we may infer that, as the copper test indicates, this juice contains only crystallizable sugar.

18. Three or four top joints, from a crystallina rattoon cane of seven months growth, yielded a juice of 4½° Beaumé, acid and astringent in taste.

This juice gave with sub-acetate of lead a light olive green precipitate, which occupied about four-fifths of the entire volume of the mixture. With the copper test a precipitate of protoxide of copper was obtained, but no reaction with iodine.

Subjected to optical analysis in exactly the same manner as the above specimens of Otaheite cane juice, this crystallina juice gave the data:

$$d = 1.040;\ t = 21°.7\ C.$$
$$a = 4°\ ;\ e = 0.545$$
$$a'' = -1°.5\ ;\ n = 0.85$$

Hence, by calculation, $x = 0.04051$; and therefore this juice contains 4 per cent. only of cane sugar. The value of D is also negative, indicating the presence of left polarizing sugar.

19. The preceding experiments were instituted with the view of determining whether, as has of late been maintained, cane sugar is a primary or secondary product in the development of the plant; whether, in other words, it is formed directly by physiological agency, from inorganic matter, or whether it has existed previously as a constituent and organic portion of the cane during its earlier immature condition, and has assumed the nature of crystallizable sugar by virtue of some chemical change at an advanced stage of the development of the plant. The facility with which those vegetable substances undergo transformation which are composed of carbon, hydrogen and oxygen, when the two latter are in the proportions requisite to form water, naturally suggests the hypothesis that sugar may be formed in plants by some means analogous to those employed in converting starch and woody fibre into grape sugar, and the latter into alcohol and carbonic acid. Yet, as all these changes seem but steps of degradation in the scale of organized being, partial returns to inorganic nature, and as it has hitherto been found impracticable by artificial means to form crystallizable sugar, which seems to occupy a higher rank in the scale of vegetable organization, it has been with seeming probability concluded that cane sugar in the growing plant results from no chemi-

cal reaction upon such substances as starch, woody fibre, &c., but is produced directly by some vital and mysterious forces different from those of mere chemical affinity, and for the discovery of which we should study rather the effects of light, electricity, &c., than mere reactions of acids, alkalies, and other chemical re-agents.

20. The probable conclusion which I would deduce from the results of the preceding analyses is, that since no other sugar than cane sugar exists in the mature joint of cane grown under favorable circumstances, while left polarizing sugar is a constituent element of new and immature joints, which also vary chemically from the former in other respects, and undergo a change not unlike that which takes place in the ripening of fruits, cane sugar is therefore formed as a secondary product, and probably from the left polarizing sugar; an opinion the opposite of that which has been of late generally accepted, and based upon investigations made by M. Hervy, in France, under the unfavorable circumstances of using canes grown in hot-houses, as well as upon the above-mentioned theoretical reasons. M. Hervy states that there was no difference in the old and new joints of the canes he used; but to every planter it is a familiar fact that new joints differ entirely from old in the countries adapted to the culture of the cane; the former being succulent in fibre, and of an astringent taste, destitute entirely of sweetness, while the latter are solid in fibre and contain a perfectly sweet juice.

*Comparative analyses of the three varieties of the cane.*

21. *Otaheite cane.*—Having cut the cane transversely into thin slices, 24.835 ounces thereof were placed in the stove used on the Saratoga estate for drying clayed sugar, and allowed to remain there for two days, when it was taken out and found to weigh 7.8995 ounces; having lost, therefore, 16.9355 ounces of water. Hence we have:

| | |
|---|---|
| Water | 68.20 |
| Solid matter | 31.80 |
| | 100.00 |

If this water be supposed to have been combined with sugar in the same proportion as shown in article 9, then we have 83.20 as the amount of saccharine juice contained in this cane—a value slightly different from that of article 9, but not more so than may justly be considered confirmatory of that result; for it should be anticipated that cane which has been ground would dry more thoroughly than that which has been merely cut into slices, the fibres of the former being, to a great extent, separated or torn apart, and thus a larger surface exposed for evaporation. If we allow a probable error for hygrometricity, we shall have very nearly 70 per cent. of water and 30 of solid matter as the most probable composition of this Otaheite cane.

22. *Creole, or crystallina cane.*—Having similarly cut into slices some Creole cane, 13.311 ounces were dried, first by exposure in a flat dish for 24 hours to the sun and action of the air, and afterwards by allowing it to remain four days in the drying oven, when it was removed, and weighed 4.158 ounces; having, therefore, parted with 9.153 ounces of water by evaporation. Hence I deduce:

| | |
|---|---|
| Water | 68.76 |
| Solid matter | 31.24 |
| | 100.00 |

A result which would give, if the juice of this cane be supposed to contain 18 per cent. of sugar, 83.85 per cent. as the amount of that juice. The difference between this result and that of article 8, is of the same degree as that described in the preceding article; and like it, for the same reasons, is rather confirmatory than at variance with subsequent experiment. Also, allowing in this case a similar probable error, we may assume approximatively 70.5 as the per cent. of water, and 29.5 as that of solid matter, composing this specimen of crystallina cane.

23. *Ribbon cane.*—Thin slices of ribbon cane, weighing 15.100 ounces, were similarly dried in the sun for 24 hours, and afterwards for four days in the oven; they then weighed 4.313 ounces, and had, therefore, lost 10.787 ounces of water. Hence we have the composition:

| | |
|---|---|
| Water | 71.45 |
| Solid matter | 28.55 |
| | 100 00 |

And if we suppose the juice of this cane to contain also 18 per cent., we shall then have 87.10 per cent. as the amount of juice. This amount also falls short of the corresponding results given in article 7. And if we make an allowance similar to those made above, then we have 72.50 per cent. of water and 27.50 per cent. of solid matter as the probable composition of this cane.

24. From the dried slices of Otaheite cane of the above experiment, article 21, I took 1 577 ounces, and digested them for several hours in alcohol of the specific gravity 0.835, which dissolved 0.0965 ounce of solid matter. Evaporated to dryness, it appeared to be chiefly sugar, but had a somewhat bitter taste, and did not dissolve completely in water. The insoluble portion weighed 0.0012, and was found to be soluble in sulphuric ether and in alcohol; it had a peculiar fragrant and balsamic odor, and seemed to be composed of wax united with an essential oil. It is this essential oil, I think, which gives to the cane and its raw juice a characteristic and slightly unpleasant taste and odor, which is lost entirely when the juice is boiled and defecated with lime.

25. The pulp was then boiled in distilled water for several hours. This water being filtered and concentrated by evaporation over a spirit lamp, gave, when treated with a mixture of alcohol and sulphuric ether, a precipitate which was mucilaginous, and had all the properties characteristic of *pectine;* and which, when dried, weighed 0.00956 ounce.

26. The pulp was again boiled in a solution of potash, in which it had steeped for nearly twelve hours. The excess of potash being neutralized by hydrochloric acid, I then obtained with tannin a precipitate, weighing, when washed and dried, 0.1063 ounce, and which contained 0.07486 ounce of albumen. That this substance precipitated by tannin could be no other than albumen I conclude because the neutralized solution gave also a precipitate with chloride of mercury, soluble in potash, but insoluble in hydrochloric acid

27. After being thus treated with alcohol, water, and aqua potassæ, the pulp was well washed, first with dilute hydrochloric acid, and then with water; and, when perfectly dry, it was found to weigh 0.56165 ounce, and seemed to consist only of woody fibre.

From the above data, I deduce the following composition of 100 parts by weight of this dried cane:

| | |
|---|---|
| Sugar | 58.95 |
| Woody fibre | 35.55 |
| Albumen | 4.80 |
| Pectine | 0.62 |
| Wax, &c | 0.08 |
| | 100.00 |

28. To ascertain the extent to which dried cane suffers deterioration when kept for a length of time, and after a sea voyage, the dried slices of each of the three varieties of arts. 21, 22, and 23, were wrapped carefully in paper, and taken with me from Cuba to Philadelphia. Several weeks after my arrival in the latter place, I subjected to analysis one ounce of each variety, following a method similar to the above, except that I precipitated the pectine with absolute alcohol only, and the albumen from the alkaline solutions by acetic acid and alcohol. I thus obtained from one ounce of Otaheite cane 0.00282 oz. pectine, 0.02206 albumen, 0.29628 lignin, and 0.67884 sugar, &c.; or,

| | |
|---|---|
| Sugar, &c | 67.884 |
| Pectine | 0.282 |
| Albumen | 2.206 |
| Lignin | 29.628 |
| | 100.000 |

Similarly, one ounce of dried Ribbon cane yielded 0.0163 pectine, 0.01672 albumen, 0.3378 lignin, and 0.62918 sugar, &c., or,

| | |
|---|---|
| Sugar, &c | 62.918 |
| Pectine | 1.630 |
| Albumen | 1.672 |
| Lignin | 33.780 |
| | 100.000 |

And from one ounce of dried Creole cane I obtained 0.01157 pectine, 0.0889 albumen, 0.2627 lignin, and 0.6368 sugar, &c., or,

| | |
|---|---|
| Sugar, &c | 63 68 |
| Pectine | 1.16 |
| Albumen | 8.89 |
| Lignin | 26.27 |
| | 100.00 |

29. To determine what proportions of the 67.88 per cent. of matter contained as above in dried Otaheite cane, soluble in dilute alcohol and hot water, and of the corresponding 62.92 per cent. in ribbon, and 63.68 per cent. in Creole cane, were respectively crystallizable cane sugar and substances resulting from fermentation or other chemical action, I made the following optical examinations two months afterwards. This delay was intentional, and designed to permit any gradual deterioration which might obtain from slow fermentation, or from changes of hygrometricity and temperature, to progress still further, and thus afford a more decided result. In the mean time, the cane was carefully kept in a dry and elevated room.

The ribbon cane, when opened, was found to be full of very small worms, and to have been greatly injured by them. No accurate analysis could therefore be made of it, and analogy alone can furnish evidence of what changes would have otherwise taken place. The worms had the appearance of those which are often bred in cheese, though smaller, and I do not doubt that they originated in the cane itself. If dried cane be liable to be attacked by such insects, this in itself constitutes a serious objection to any method of manufacture based upon desiccation and subsequent maceration.

The Otaheite and the Creole cane had, however, all the appearance of being perfect, alike in color, taste, and every other external indication. I mixed them with three parts of water exactly, so as to form 25 per cent. solutions, repeatedly shaking the mixture, and compressing the pulp with a wooden instrument similar to the ordinary lemon squeezer, in order the more effectually to extract any soluble matter. The solutions were slightly colored,

and they were therefore decolorized with boneblack, and filtered, after which they were observed with the following results:

For the Otaheite cane:

$$a = 12°;\ d = 1.044;$$
$$a'' = -5;\ n = 0.9;$$

and therefore by calculation $x = 32.7$ per cent. of cane sugar.

For the Creole cane:

$$a = 16°;\ d = 1.035;$$
$$a'' = -7°.5;\ n = 0.9;$$

and therefore we deduce $x = 45.4$ per cent. of cane sugar.

For the Otaheite cane we have for the value of D in the equation,

$$S + D = a,$$

the negative value, $D = -1.22$; and similarly for the Creole cane, $D = -1.18$. Hence it follows that in each of them there has been formed by fermentation a large proportion of left polarizing matter.

As a check upon these optical determinations, I subjected the solutions to the copper test of Trommer, and obtained for each a large precipitate of the red protoxide of copper. With a warm and dilute solution of caustic potash, the dark color produced by fermented sugar was readily given when slices of the cane were subjected to its action.

30. These results should therefore settle the point that dried cane cannot be kept long without decomposition, and consequently that it cannot be exported without loss, to be manufactured in foreign countries by the process of maceration. Many have thought that the cane sugar industry could be thus completely and advantageously revolutionized. But the proposition may now, I think, be regarded as no longer worthy of serious consideration; especially since the above results obtained by the method of polarization, and checked by the copper and potash tests, are confirmatory of the labors of M. Dupuy in Guadaloupe, who obtained from freshly dried cane, stripped of its rind, 66 per cent. of pure sugar, but four months afterwards could extract therefrom but 34 per cent., which was clammy and dark colored. In comparing this result with those given above, it must be borne in mind that the rind as well as the pulp of the cane was used, so as to render the circumstances as nearly as possible like those which would probably be followed on a large scale.

An analogous fermentation which takes place in dried beets has been studied by Messrs. Frémy and Boutron, who found that lactic acid is gradually formed at the expense of the sugar; but the presence of left polarizing matter indicated by the negative values of D, in my experiments upon dried cane, clearly shows that this transformation is attended with phenomena which require further investigation before it can be fully understood.

*Analysis of some of the feculencies contained in Otaheite cane juice.*

31. For the purpose of ascertaining what is the nature of the greater part of the feculencies contained in cane juice, and which separate by gentle heat alone, I took a portion of the scum from the clarifier, heated to 140° Fahrenheit, and subjected it to analysis, with the following results:

The feculencies as taken from the pan were partially dried by exposure to the air, but they were so retentive of moisture that I found it impracticable to dry them thoroughly without heat, which would probably change the combinations of their elements, and was therefore avoided; and when mixed with water, they formed a mucilaginous mass, which could not be filtered. A portion of the still moist feculencies being then carefully weighed, was digested in boiling alcohol of the strength of 95 per cent., and the mixture subjected to filtration on a counterpoised filter. The solid matter in the filter was gently and freely washed with fresh alcohol, after which it formed a perfectly dry pulverulent mass, and was equal in quantity to 11.04 per cent. of the original matter treated with alcohol. By evaporation this alcohol yielded 1.64 parts of wax, and a small portion of an essential oil; it had therefore taken up 87.32 parts of water. Hence the scum examined is composed of 87.32 per cent. of water, and 12.68 per cent. of dry matter.

From these results, united with those of an analysis of the portion insoluble in strong alcohol, I obtained, as the composition of the 12.68 per cent. of dry matter in the feculencies which separate from Otaheite cane juice by heat alone:

| | |
|---|---|
| Woody fibre | 70.5 |
| Albumen | 14.0 |
| Wax | 12.9 |
| Silica | 1.3 |
| Phosphate of lime | 1.1 |
| Oxide of iron | 0.2 |
| Essential oil | a trace. |
| | 100.0 |

By washing a considerable quantity of these feculencies with sulphuric ether, which was afterwards allowed to evaporate spontaneously, I succeeded in obtaining several drops of the essential oil which I had previously detected in the dried cane. They had the taste of raw cane juice, though in much greater degree; were insoluble in water, soluble in alcohol and ether, and volatilized at a temperature below the boiling point of water, exhaling a peculiar odor.

32. If the temperature of the clarifier had been more elevated, yet not allowed to approach the boiling point, say 175° to 200° Fahrenheit, a larger proportion of albumen would doubtless have

been coagulated and formed part of the scum; while the wax would have been diffused through a larger mass, and consequently appeared less considerable. No substance soluble in water at 140° Fahrenheit could of course be found in this scum, and it contained neither pectine nor any alkaline salts; and as no temper lime had been added to the juice from which it was taken, lime existed in it only in the form and proportion of the phosphate of lime, which constituted an element of the living plant.

With reference to the oxide of iron, I should attribute its presence rather to accidental circumstances arising from the use of heavy iron rollers for expressing the juice. The surfaces of these rollers are subjected constantly to oxidation in contact with air and moisture, as well as to the friction of the canes which pass between them, covered often with particles of sand; and that the expressed juice should contain mechanically a slight portion of insoluble oxide of iron, which may become attached to the floating woody fibres, or be gathered into the scum by the coagulated albumen, is therefore to be expected.

## CHAPTER II.

### ON THE VARIOUS PROCESSES FOLLOWED IN THE MANUFACTURE AND REFINING OF SUGAR.

At first sight it would appear that the arts of the manufacture and refining of sugar are entirely distinct and different; but a more careful consideration leads to the conclusion that they might almost be regarded scientifically as one single art; pursued, however, by different persons, and generally in countries of very dissimilar climate, far remote from each other.

Thus sugars of the East and West Indies are refined in Russia, England, Holland, France, the United States, and other countries; the luxuriant growth of the tropics and crude processes of extraction furnishing an article which is afterwards refined by the industry and chemical skill of northern nations, in climates the most favorable for this latter operation.

France only, of the most important and powerful nations, affords an instance, in her beet sugar industry, of a country in which sugar is produced, refined, and consumed, without much change of place and climate. Hence I am inclined to think that perhaps the chief reason why the manufacture of cane sugar has been regarded as an art totally different from that of sugar-refining, is one rather of difference of latitude and longitude, and of persons, than of a chemical nature.

And believing, as I do, that the sugar planters of the south would find it greatly to their advantage to acquaint themselves with, and introduce into their sugar-houses, the beautiful and perfect methods employed by northern refiners, I shall discuss together the processes practised alike by both, though with different skill, and which, if separated geographically, are still chemically the same.

Both the planter and the refiner have the same problem to per-

form; that of obtaining crystallized sugar by evaporation from impure solutions thereof. Both resort to methods closely similar, but they differ much in circumstances; the planter being an agriculturist, much of whose time and care are necessarily given to the culture of the beet or cane, which constitutes his raw material, and who has generally to contend with the disadvantages of climate, with the ignorance and stupidity of negro workmen, and with the want of those facilities for procuring and repairing machinery usually so readily commanded by the refiner; while the latter, employing intelligent and skilful workmen, and possessing the capital requisite for purchasing the raw sugars imported for him by merchants, experiences no such losses as the failure of crops, and in his colder climate is free from the necessity of working very rapidly, to avoid those accidental fermentations to which the tropical planter is so much exposed.

Hence, in considering the processes employed by the planters in contrast with those followed by the refiners, great allowance must be made for the different circumstances in which they are placed, if we would judge correctly of their comparative enterprise and intelligence.

The above-mentioned processes of manufacture and refining may be classed under the following distinct heads:

1st. *Obtaining a saccharine solution from the raw material;*
2d, *Defecation or clarification;*
3d, *Filtration;*
4th. *Evaporation;*
5th. *Crystallization;*
6th. *Drying;*
7th. *Working of second products;*
8th. *Use and treatment of animal charcoal.*

And under these heads I shall discuss, in close connexion, not only the present but the past condition of these two arts—past and present being terms applicable rather to stages in the progress of knowledge, than of general practice; for many refiners, as well as planters, still continue to use the old and faulty methods, which should be abandoned. In doing which, however, they are perhaps oftener governed by necessity than choice; by want of ability to procure new machinery, than of inclination to adopt it if attainable. And here I may remark, that is only within a few years that any very important improvements have been made in the sugar industry of the world.

The art of refining sugar has been entirely revolutionized by the admirable invention of the vacuum pan of the Hon. Edward Charles Howard, patented November 13, 1813, and carried into practice some time afterwards by Mr. Hodgson, together with the employment of animal charcoal for clarification, recommended first, I believe, by M. Derosne, and rendered practicable by MM. Payen and Pluvinet, who manufactured it on a large scale.

While, also, the manufacture of beet sugar, originating in France at the time when her ports were blockaded by the English navy, stimulated by special privileges and rewards granted by the govern-

ment, and aided by the combined science of that nation, has served to test apparatus and methods the most varied, and to trace out chemical relations and reactions the most intricate and important.

In those countries where the sugar-cane flourishes, (the purest and the richest in saccharine matter of known plants,) little improvement took place, or was even attempted, until very recently, if we except the successful experiments of M. Dutrone, in St. Domingo, before that island reverted to barbarism by the massacre of its white inhabitants. Lately, however, the planters of the tropics have begun to appreciate and avail themselves of the perfected apparatus and methods of the refiners and beet-sugar manufacturers, and with results the most profitable and advantageous.

On an estate in Cuba, I have seen the juice of the cane purified with lime and animal black, and evaporated in a vacuum pan, yielding white sugar only, and little or no molasses; the sirup drained from the first crystallization being evaporated a second time, and yielding *white* sugar, in color only a shade darker than the first, and of excellent grain.

Such estates constitute exceptions, however; while for a very large number the arrangements and methods described by the author of the *Histoire Naturelle du Cacao et du Sucre*, published in 1720, the oldest treatise I have seen on the subject, would answer almost as well for this day as that in which he wrote. The use of the steam engine to grind the cane, and the substitution of the mill with horizontal in place of that with vertical rollers, being almost the only improvements extensively introduced.

SECTION I.—*On obtaining a saccharine solution from the raw material.*

Under this head I shall discuss the methods employed for dissolving brown or raw sugars by the refiners, and those employed for the extraction of the juice both from beets and the cane, as well as the various modifications which have been either attempted or merely suggested.

1. In refineries conducted upon the old or German method, it is customary to dissolve the sugar with lime water, in an open hemispherical copper pan, exposed to the direct action of the fire; using only the quantity of lime water requisite for complete solution, and stirring in at the same time a quantity of bullock's blood, to commence the operation of clarification.

2. In refineries conducted on more modern principles, the raw sugar is usually dissolved in about 30 per cent. of water, in copper vessels, heated by steam, by means of a double bottom, or a serpentine tube pierced with holes, through which jets of steam issue and furnish, by condensation, part of the water of solution. The heat caused by steam issuing from such a serpentine tube is said not to exceed 180° Fahr. To enable the next operation (that of clarification) to be performed, the double bottom, with the use of

steam of rather higher pressure, becomes necessary. The peculiar mechanical effects produced by the jets of steam in this operation have caused it to receive the name of the *blow-up*. The proportion of water used for dissolving the sugar should not vary much either way from 30 per cent., the quantity which forms a saturated solution at the ordinary atmospheric temperature; for if less were used, the sirup would not run freely through, and might even, if cooled, crystallize in the filters; and if greater, the excess of water would cause subsequent loss of fuel and time in its evaporation. During this operation, and indeed as part of it, a quantity of lime water and of fine animal charcoal is added to the solution of sugar; the purpose of which we shall discuss under the next division of our subject—that of defecation, to which it properly belongs.

3. The complete extraction of the juice from the beet is a problem upon which much ingenuity has been exercised in France; and the various contrivances and experiments which have consequently been either successfully or unsuccessfully tried, are well worthy of the attention of those interested in the manufacture of cane sugar; for it is thoroughly established that no less than 25 per cent. of all the juice contained in the cane is lost in the usual mode of working, being retained by the spongy fibres of the begàssa; and if improvements are to be made, or attempted, to get rid of this loss, it is certainly important to gather from the experience of the beet-sugar manufacture all the light which analogy can afford.

4. *By pressure.* The beet, before it is subjected to pressure to obtain its juice, is usually first well cleaned, to remove adhering earth, and then reduced to a finely divided state by rasping. The details of these operations I shall not describe, because, as nothing similar has been attempted or thought desirable for the cane, such details are rather matters of curiosity than of importance in connexion with the objects of this report; and I may therefore be allowed to refer to the works upon that particular branch of the sugar industry, for the gratification of such curiosity.

After being thus finely divided, the pulp of the beet is pressed, either by means of Bramah's hydrostatic press, (too well known in the arts generally to need description here,) or by means of the press of M. Pecqueur, which acts continuously, and consists of a forcing pump, to push the pulp, as it comes from the rasp, between two revolving hollow cylinders, pierced with holes and covered with metallic gauze.

This latter press gives less juice than the former, chiefly because it moves too rapidly to allow sufficient time for the juice to flow out. Both perform their office, however, very imperfectly; for it is asserted that a portion of the pulp can be more fully deprived of juice by squeezing it in the hand than the mass becomes which is subjected to the action of either of the above-mentioned presses.

The amount of juice obtained is usually 75 per cent.; while 95 per cent. is contained in the beet. There is, therefore, a loss of about 20 per cent.

M. de Mesmay extracts from pulp thus pressed the further amount of 15 per cent. of juice by subjecting it to the action of steam, in close vessels. The steam appears to destroy the cellules left unbroken by the rasp, and to allow an additional escape of juice by a second pressure.

In some establishments 15 per cent. of water is added to the pulp as it comes from the rasp; after which, it passes to the press. In others, a similar quantity of water is poured in a fine stream upon the rasp itself; and it is contended that a juice is thus obtained of equal density, and in larger quantity; the theory being that the water acts by displacement, being absorbed by the pulp in place of the juice it contains.

5. Many experiments have been tried on a large scale in France, with the purpose of discovering, if possible, a process for obtaining all the juice contained in the beet without injury to its quality. They appear, however, to have been attended with but little success; and their discussion here might therefore be omitted, were it not that much instruction may be derived from these attempts, with reference to the difficulties and the chemical facts which they render manifest, and which equally relate to the cane and the important problem of the extraction of its juice.

Almost all of these attempts have consisted in washing the rasped pulp, or slices of the beet, with water, according to methods variously modified, so as to give saturated saccharine solutions with as little admixture of foreign matter as possible. But nearly all such methods have been attended with the disadvantage of increasing the quantity of water to be evaporated, and the consequent expense of fuel. The simplicity of the apparatus proposed, and the small investment of capital required by most of these processes, together with an increased amount of sugar obtained, have, however, caused their authors generally to imagine that they would more than compensate for the additional consumption of fuel they require.

6. *By maceration in hot water.* The process of maceration in hot water of M. de Dombasle is one of the best known, and most thoroughly tested. M. de Mesmay having worked his establishment for some time according to this method, at length abandoned it, and adopted the usual method of rasps and presses. The saccharine solution obtained was of the common density, by reason in great part of foreign matter dissolved, being indeed less rich in sugar. The defecation was attended with difficulties; the feculencies did not gather well, were very soft, and even seemed to be of a different nature from those obtained from mere expressed juice.

M. de Dombasle having found that cold water would not extract the juice from slices of beet, but that it readily unites with hot water, attributed this fact to the vegetable life of the beet: it is simply explained, however, by the action of the heat upon the albumen and cellules, coagulating the former and rupturing the latter, so as to permit the saccharine matter to be dissolved. Adopting the theory that the resistance to the solvent power of cold water

was a force of life, M. de Dombasle concluded that if this life be destroyed in any way, then there would be no longer any trouble found in extracting the juice by simple maceration in water; and, therefore, that if the juice contained be treated with a quantity of water equal to itself, this water would form with it a uniform solution, and consequently unite with one-half of the saccharine matter.

The sirup thus formed being poured on a fresh portion of slices of beet of equal richness and weight with the former, should take up one-fourth to constitute a homogeneous liquid, and have a richness of three-fourths of that of the juice. Similarly, by a third operation, it would acquire one-eighth, and so on; thus acquiring, by a series of similar washings of equal and fresh portions, the successive richnesses, $\frac{1}{2}$, $\frac{3}{4}$, $\frac{7}{8}$, $\frac{15}{16}$, $\frac{31}{32}$, $\frac{63}{64}$, $\frac{127}{128}$, $\frac{255}{256}$, etc.; while a portion of pulp, subjected to successive washings with fresh water equal in quantity to the juice it may contain, would have the successive decreasing richnesses, 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, etc.; yielding to each successive portion of water one-half of its soluble contents.

These ingenious views of M. de Dombasle, though predicated on a theory which substituted mysterious vital action for simple physical and chemical causes, led to results such as his conclusions call for, and were put in practice by manipulations similar to those used by the manufacturers of saltpetre, who employ a series of tubs, arranged so that the solution from one passes to another, the more exhausted material coming in contact with fresh water, and the nearly saturated solution acting on the fresh portions.

M. de Dombasle employs a series of tubs, arranged not as in saltpetre works, one above another, but on a level, and in a circle. The pulp is lifted from one and placed in another, by means of a crane.

However ingenious, this method is very faulty, for chemical reasons: the hot water dissolves not only the saccharine juice, but also a large proportion of the pectine, while much of the albumen coagulates in the pulp. Hence the soft feculences, the difficulty of collecting them, and their altered nature. As a general rule, extraction by hot water must dissolve pectine, and leave albumen coagulated in the pulp, and is therefore to be avoided.

7. *By maceration in cold water.* Although, as above stated, cold water will not extract the saccharine matter from slices of beet smoothly cut with a knife, or by other mechanical means, it yet abstracts it freely from the pulp made by rasping; and therefore various ingenious methods of maceration have been contrived, having for their objects economy of manual labor, continuity of operation, and the subjection of the pulp to the action of water in such manner as to expose to fresh water that which has been already nearly exhausted, and fresh pulp to the solution which is nearly saturated. The contrivances resorted to consist generally in modes of conveying the pulp and water in opposite directions—the pulp passing out where the fresh water enters, and conversely entering where the latter escapes.

Thus MM. Martin and Champonnois employed an inverted syphon,

through which pass, in opposite directions, a stream of water and an endless band, to which small transverse disks are attached, by which the pulp is carried through the syphon.

But of these mechanical arrangements, that which is best known, and which has been most used, is the *lévigateur* of M. Pelletan, a rather complicated machine, answering the same purpose as the inverted syphon and endless band just described—that of carrying the pulp through a stream of water flowing in the opposite direction; and consisting of a sort of inclined Archimedes screw and trough, divided into numerous compartments, so arranged that each spiral of the screw shall remove the pulp from one division or compartment to that above, from which the solution flows by reason of the inclination given to the whole apparatus—the water entering at the last or upper division, where also the exhausted pulp passes out.

These processes extract the albumen and saccharine matter, but leave the pectine in the pulp; hence the liquor obtained is easily defecated, and yields a good sugar; while the additional quantity of water not only renders fermentation of more easy occurrence, but also requires for evaporation a greater quantity of fuel—an objection of the highest importance when fuel is not very abundant.

8. *By displacement.* Besides the above-mentioned processes, others, depending upon the principle of displacement, have been tried, though with little success, for the extraction of the saccharine juice from the rasped pulp of the beet. I will here give the results obtained by M. Baudrimont, which serve to show the difficulties which are met with. He used tubes about three inches in diameter, into which he placed the rasped pulp, and then filtered through it a portion of water, uniting the effects of pressure, maceration, and filtration, and subjecting the upper and more exhausted strata to fresh water, while the lower portions were acted upon by the more saturated solution, so as to combine many advantages.

At first, the pulp was submitted to the pressure of a short column of water; the juice flowed out very slowly, and two-thirds of it were expressed or displaced without mixture with water. The remaining third gradually filtered from the tube in aqueous solutions, less and less rich, but did not seem entirely dissolved, until a quantity of water had been used equal to four times that of the residual juice; so that, to abstract completely the juice from a portion of rasped pulp, a quantity of water equal in volume to that of the pulp must be employed.

But the operation required 12 hours for its completion—an objection of great moment. To shorten the time, the pressure was varied by increasing the height of the column. Under the pressure of about 20 feet water, in the same filter, the pulp was exhausted in about half an hour, and required only half of its own volume of water. Hence, M. Baudrimont supposed that greater pressure would give even more favorable results. He therefore constructed an apparatus provided with a forcing pump, by which a pressure of

fifteen or twenty atmospheres could readily be commanded. The pulp of the beet in this apparatus yielded about 75 per cent. of its juice, unmixed with water; and the remaining 25 per cent. came away mixed with an equal quantity of water; so that the pulp was completely exhausted by a quantity of water equal in volume to one-fourth of the juice it contained. In these experiments a fact was noticed by M. Baudrimont, that, as the aqueous solution became less saccharine, it acquired a strong, disagreeable taste of the beet. Subsequently, experiments were tried by M. Martin, with still greater pressures, by means of a hydraulic press, worked rapidly by a steam engine; the power was so great, and acted so promptly, that the water acted simply as a piston, compressing the pulp, and expelling its juice by pressure only; the pulp forming a solid mass through which the water could not flow, and which thus constituted an obstruction not to be overcome. These experiments prove that in the action of displacement tubes under pressure, the solution flows faster in proportion to the pressure; that one liquid cannot displace another entirely without mixture, but that this mixture, as well as the quantity of the displacing liquid, is inversely proportional to the pressure. To these results there is a limit, however, if the pressure be too great, in which case displacement becomes impracticable, probably by virtue of capillarity.

M. Legavrian has patented a process for displacement, in which he substitutes atmospheric pressure by means of a vacuum below the pulp, from which it is separated by means of a diaphragm pierced with holes, the vacuum being formed either by an air pump, or by the condensation of steam.

From the preceding results, it follows that *displacement*, like *maceration*, is attended with the difficulty of mixing the juice with water, and therefore involves loss of fuel. It has also the disadvantages of not acting continuously, and consequently requires much manual labor. If cold water be employed, the solution defecates readily, and yields good sugar; but hot water would extract the pectine, and thus detoriorate the saccharine solution.

9. *By desiccation.* Besides the above methods of pressure and maceration of the fresh beet, there is one which has been tried in Bavaria by Mr. Schutzenbach, and which consists in drying the beet, cut by a machine with knives into small parallelopipeds, after which it is pulverized, and the sugar extracted by infusion in water acidulated with sulphuric acid. The drying is performed by means of stoves, and the solution in acidulated water by manipulations much less effectual and neat than the systematic modes of M. de Dombasle and others above described. The sulphuric acid is supersaturated with lime, and the subsequent operations of defecation, filtration, evaporation, &c., are then performed in the usual manner, furnishing sugar of good quality. After drying, the pectine remains in the insoluble part of the beet, and the saccharine solution obtained is therefore easily defecated.

Whatever advantages this process may possess, it is impossible that it can be attended with economy of fuel; on the contrary, by the substitution of an equal quantity of water for that originally

contained in the juice, *double the amount of water* has to be evaporated, and consequently double the necessary proportion of fuel would be consumed.*

Mr. Schutzenbach also invented a process of extraction of sugar from dried beets by means of alcohol; one which seems to possess nothing to recommend it to the attention of planters, while it is not only very costly, but also attended with great danger of loss of property by fire, by reason of the extreme inflammability of the solvent employed.

Although the disadvantage of waste of fuel constitutes a serious objection to the employment of the method of desiccation, yet, if the slices of beet, dried on the farms where they are cultivated, be transported thence to large establishments or refineries for the extraction and refining of the sugar contained, it is highly probable that this method may be found profitable and perfectly successful. Yet, according to the researches of MM. Frémy and Boutron, dried slices of beet undergo a very gradual change or fermentation, lactic acid being produced at the expense of the sugar; they should therefore be subjected to the subsequent operations without loss of time, since they cannot be kept long without deterioration.

10. The above-mentioned constitute all the methods which have been tried on a large scale for the extraction of the saccharine matter contained in the sugar beet, and of which I have any knowledge. From a view of the whole, the following conclusions suggest themselves as the general facts established with reference to this subject:

It is impracticable, by the mechanical means heretofore employed, to extract more than about 75 per cent. of the saccharine juice contained in the beet. From the pulp which has been once subjected to pressure, about 10 per cent. more of juice may be expressed if it be first moistened, or subjected to the action of steam in close vessels, the water acting chiefly by *displacement*, filling the capillary interstices of the pulp, and displacing the juice therein retained. No other method hitherto employed is free from objections of a serious nature; all of those which employ maceration, whether with hot or cold water, with fresh or dried beets, being attended with waste of fuel, while one, that with alcohol, is even liable to dangerous accidents. Hence it follows that the only important improvement made in the beet-sugar industry, in the extraction of the juice by other means than mere mechanical pressure, is that of steaming or moistening the pulp. Of the presses employed, the hydrostatic and the press Pecqueur, the latter only acts continuously, and offers to the planter of the cane nothing from which he can profit, inasmuch as it consists simply of a roller or cylinder press, combined with a sort of forcing pump for feeding it with rasped pulp.

*See Appendix, note E.

11. *On the extraction of the juice of the sugar cane.* I do not intend here to enter into a detailed description of the ordinary sugar mill with horizontal rollers, so well known to every planter, nor even to give a comparative view of the methods practised in different countries at the present time, or which have at different times been used in any one country; for the rough methods formerly in general use, and still followed where improvements have not been introduced, furnish nothing new and instructive to the intelligent planter, familiar with the old vertical mills and their imperfections. Neither would a discussion here of the relative effects of water-power, steam-power, and the power of cattle, prove of any value. These are matters too well understood to require investigation or comment. With reference, however, to the horizontal roller-mills, the following observations may not be to some without interest and instruction:

12. During the grinding season, when the chief object of many seems to be rather to hurry through with the crop as rapidly as possible, than to obtain the largest quantity of sugar of good quality, the grinding of the cane is often peformed in a very improper and ineffectual manner. Whether or not this stricture applies as well to Louisiana as to Cuba and the other West India islands, I cannot speak from knowledge; but from all I learn, I presume it does. A general spirit of haste and hurry pervades the whole force of the plantation, and in consequence much is done without system. In grinding, to obtain the proper yield, the most perfect system should be strictly observed. The mill should be not only regulated to a uniform speed, but should be of sufficient power to work off the entire crop without requiring the speed to exceed the rate which will permit the juice to flow off readily before the begassa is liberated from the mill, so that this begassa may not in expanding act as a sponge, to absorb a large proportion of the expressed juice. The importance of grinding at low speed is rendered evident by the following mean results of numerous experiments made by the Marquis de Ste. Croix, a very intelligent planter of the island of Martinique, and which I extract from a work* he has written on the manufacture of sugar.

With the same mill, and its rollers set in the same way, the juice obtained constituted 45 per cent. of the weight of the canes ground when the rollers made six revolutions in a minute, and 70 per cent. when the velocity was only two and a half revolutions per minute; a difference of 25 per cent.

As the surface developed is for an equal number of revolutions proportional to the diameters of the rollers, M. de Ste. Croix asserts that a good result will be obtained by rollers which develop a surface of four or five yards in length per minute, so that a roller of two feet diameter should make from two to two and a half revolutions per minute.

And if it be objected that this velocity is insufficient to express the requisite amount of juice in a given time, then the length of the rollers should be increased, and, if necessary, also the power

* "Fabrication Actuelle du Sucre aux Colonies: Paris, 1843."

of the engine. It is the quantity of juice required per hour, under circumstances the most favorable for perfect extraction thereof, which should determine the power of the engine to be employed.

If any planter should have already erected a mill with an engine and rollers, which, to grind his crop, must be worked at a speed considerably higher than that which gives a maximum yield of juice for a given weight of cane, then he will find it greatly to his advantage and profit to employ no greater velocity than is absolutely requisite for the grinding of the crop. A large quantity of cane imperfectly ground may yield a larger and better result than a smaller quantity thoroughly expressed. And when frost or other disadvantageous circumstances require the cane to be ground as rapidly as possible, it may be often impracticable for the planter to grind it perfectly. In such case, he must, perhaps, consent to lose a portion of the juice which he otherwise would have obtained; but while there is no such necessity for hasty and imperfect work, there is no reason for fast grinding.

In Cuba I have seen the cane ground on some estates far more rapidly than seemed to be requisite. For several hours the mill would be run at a high speed, and the juice collected in large reservoirs, where it would often stand a considerable length of time before it could be drawn off for evaporation. And when once these reservoirs are filled, the grinding ceases until they are emptied, when it commences again; the negroes meanwhile having been engaged in other work than that of feeding the mill, or more frequently having stowed themselves about the sugar-house in snug corners, and fallen soundly asleep, heedless of noise or care. It is therefore evident that the same amount of work might be done on such estates, or rather the same quantity of cane ground, at less velocity of the rollers. Nor would it require a larger force of negroes, or more work of those employed, for it is self-evident that the number of negroes required to feed the mill is proportional to the quantity of cane ground in a given time, or to the velocity of the rollers; and that, therefore, if this velocity be diminished, the number of negroes may be proportionally decreased; and if it be deemed requisite to allow short intervals of rest to the negroes even during the working hours, then it seems to me that this would be systematically and far better done by dividing the feeding gang into watches, to relieve each other from time to time, the mill meanwhile grinding uninterruptedly. Nor would the juice thus be exposed to the danger of fermentation by long standing in the reservoirs; an accident which often happens, and for which the poor negro, who is charged with keeping them clean, is sometimes most unjustly blamed.

So to regulate the quantity of juice expressed in a given time that it shall furnish the evaporating kettles with a continuous supply equivalent to the steam constantly passing off from them, is therefore the task which the mill should perform; and by the performance of which, with the proper velocity of the rollers, the crop is made to yield the largest amount of sugar.

13. I have heard it objected to the more perfect expression of the juice contained in the cane, that the begassa would thereby be injured for use as fuel. On the contrary, by abstracting that juice, the begassa can be much more readily and completely dried; for the juice retained in the spongy tissue undergoes viscous fermentation, and forms a deliquescent substance. That moisture does not contribute to the value of any combustible for the purposes of fuel, is evident from the fact that heat is lost in converting it into steam, and thus driving it off before combustion ensues. Hence it follows that to leave any quantity of saccharine juice in begassa involves even a double loss—first, of the sugar therein; and, secondly, of the fuel expended in converting a portion of said juice into steam.

14. Although it would appear from the above that the cane should yield 70 per cent. of juice, yet the usual proportion obtained probably does not generally exceed about 60 per cent. In Cuba, according to M. Casaseca,* professor of chemistry in the University of Havana, the different kinds of cane gave the following results:

*Ribbon cane*, ground by water-power, on the *Ingenio Alesandria*, an estate belonging to Count O'Reilly, yielded:

| | |
|---|---|
| Juice | 45 |
| Begassa | 55 |
| | 100 |

*Creole cane*, ground by steam-power, on the *Ingenio Economica*, belonging to Don Pedro Diago, gave:

| | |
|---|---|
| Juice | 35 |
| Begassa | 65 |
| | 100 |

*Otaheite cane*, ground by mill turned by oxen, on the *Ingenio Coca*, belonging to Don Ambrosio Romero, gave:

| | |
|---|---|
| Juice | 56 |
| Begassa | 44 |
| | 100 |

*Otaheita cane*, ground by water-power, on the *Ingenio Ilolanda*, belonging to Don Lorenzo Montalvo, yielded:

| | |
|---|---|
| Juice | 57 |
| Begassa | 43 |
| | 100 |

The juice obtained from these different varieties of cane was of different density, and doubtless, therefore, the canes varied much in composition; but all of these results fall far short of the amount

*Ann. de Chim. et de Phys., t. xi., p. 39.

of juice contained, and which might or should have been expressed.

15. I have no authentic data from which I can determine the yield usually obtained in Louisiana or in the British West Indies. In Martinique the results probably correspond nearly with those which M. Dupuy has given for Guadaloupe, and which I here embody, as perhaps not uninteresting or unimportant to planters.

| Name of plantation. | Juice. | Begassa. | Degree of juice Beaumé. |
|---|---|---|---|
| | | | ° |
| Basse Terre | 68.5 | 31.5 | 10.5 |
| Le Bildary | 68.2 | 31.8 | 9 |
| Do. | 63.5 | 36.5 | 10 |
| Dolé | 58.5 | 41.5 | 10 |
| Moyencourt | 65.5 | 34.5 | 10 |
| Jabrun | 61.5 | 38.5 | 10.5 |
| Do | 61.4 | 38.6 | 10.5 |
| Do | 60.5 | 39.5 | 10.5 |
| Mayol | 58.0 | 42.0 | 10 |
| Mahuzié | 64.5 | 35.5 | 9.5 |
| Boisdebout | 63.0 | 37.0 | 10 |
| Desvigne | 57.0 | 43.0 | |
| Changy | 61.0 | 39.0 | 10 |
| La Sarulle | 59.0 | 41.0 | 10 |
| Carrire | 60.0 | 40.0 | 9.7 |
| Verdier | 58.0 | 42.0 | 10 |
| Jabrun Baie Mahault | 63.3 | 36.7 | |
| Viscel | 60.0 | 40.0 | 10.5 |
| Honelbourg | 59.0 | 41.0 | 9.5 |
| Destrelea | 58.0 | 42.0 | 9.5 |
| Giraud | 60.0 | 40.0 | |
| Longchamp | 55.0 | 45.0 | |
| Ardène | 57.5 | 42.5 | |
| Ruillier | 57.0 | 43.0 | |
| Sylvain-Montaligre | 55.0 | 45.0 | |
| Souques | 55.0 | 45. | |
| Lalanne | 58.0 | 42.0 | |
| Pouzoles | 56.0 | 44.0 | |
| Veruias | 61.5 | 38.5 | |
| Laurillard | 62.0 | 38.0 | |
| Kayser | 58.0 | 42.0 | |
| Lamarchandière | 60.0 | 40.0 | |
| Lilet | 55.0 | 45.0 | |
| Lecluse | 57.0 | 43.0 | |
| Clunny | 57.5 | 42.5 | |

Hence it appears that in that island the yield of juice is about 60 per cent.

The injury done to the begassa in the mill by crushing the fibres is slight, if the rollers be made to move uniformly and with the same velocity. And M. Duprée states that 65 or 66 per cent. may always be readily extracted without any mechanical deterioration of the begassa as a fuel.

16. To obtain a larger proportion of juice, M. Péligot has recommended that the begassa be steeped in water, and pressed a second time in the mill. A weak solution of the juice is thus made, from which a considerable quantity of sugar may be obtained. M. Duprée states that he has thus increased the yield 20 per cent., without alteration of the machinery or crushing the begassa. To evaporate this water requires, of course, additional consumption of fuel; which, where fuel is scarce, constitutes a serious objection to M. Péligot's process. But where fuel is superabundant, this process is well worthy of the attention of planters:*

17. Another method of increasing the yield of juice has been proposed by M. Payen, and which may be preferable to that of M. Péligot. Both, it will be seen from what has been given above, are analogous to processes employed in the beet-sugar industry, and may therefore be considered as based upon experience as well as theory. M. Payen suggests that the mill be made of five rollers instead of three; and that between the two top rollers there be placed longitudinally a pipe, pierced with numerous small orifices, to permit jets of steam to issue, which would be absorbed by the begassa, and, acting by displacement, allow the juice to be expressed which is firmly held by capillary forces in the spongy tissue of the begassa; the steam-pipe being supplied from the boiler of the engine, and the mill enclosed in a case of sheet iron to prevent loss of steam. Besides furnishing more concentrated products, and therefore requiring less fuel, this process would be attended with greater economy of time and manual labor than that of M. Péligot. The steeping in water required by the latter needs time, and the second grinding of the moistened begassa nearly doubles the work of the mill for the entire crop. Besides, weak aqueous solutions of sugar or cane juice are peculiarly liable to fermentation; an accident from which in M. Payen's method the juice is protected by the heat of the steam.

18. I am not aware that any processes similar to those of *maceration* in the beet-sugar industry have yet been attempted or recommended for the cane. It has, however, been suggested, that if the canes be cut, by revolving knives, into traverse disks or slices, these might be exported to foreign countries, where the sugar could be profitably extracted and refined. The apparatus requisite for a

*See note C, of the Appendix.

plantation would consist, then, simply of one or more such cutting machines, driven by animal or water-power, and drying stoves or kilns. The consumption of fuel could not be much less than that required by the present system of working; for inasmuch as the effect to be produced in both methods is the same, namely, the evaporation of the moisture or water contained in the cane, the fuel required would vary only by reason of a difference in the economy of the heat, as in the two methods applied.

But there is an objection which has been urged against this last method, that the slices of cane cannot be kept without fermentation, lactic acid being formed at the expense of the sugar they contain. M. Dupuy examined a portion of cane, which, having been stripped of the external rind and dried, yielded about 66 per cent. of crystallizable sugar. Four months after, it had become soft and colored, and was found to contain only 34 per cent. of sugar. On this subject I have also tried several experiments, which are given in the preceding chapter.

## Section II.—*On defecation.*

To separate from the expressed juice foreign matters which are combined chemically with it, and by means which will not injure the sugar contained, constitutes the first and by far the most important and difficult operation of the manufacture of sugar. Upon this operation, commonly called *defecation*, every subsequent one chiefly depends. If it be properly performed, the rest present comparatively little difficulty; but if errors be committed in it, their consequences cannot be subsequently remedied, and must therefore affect the final result. The impurities which are simply mixed with the juice require but little skill or knowledge for their separation, sieves of copper wire and filters of cloth being sufficient for that purpose. But to separate the albumen, pectine, salts, &c., which are dissolved in the saccharine juice, so as to permit the latter to be extracted in a pure crystalline form, is a delicate chemical problem, requiring skill and some knowledge, both theoretical and practical, of the nature and properties of the various substances contained in the juice, as well as those employed as agents of separation.

In this section I propose to describe and discuss the processes of defecation heretofore employed or attempted on a large scale.

1. *Refining sugar.*—Refiners employ for their raw material sugars from which nearly all the foreign matters originally contained in the juice of the beet or cane have been carefully removed. Besides molasses and the products of fermentation, there is, indeed, little else mixed with even the most inferior muscovado sugars except a small quantity of pieces of dried cane or other dirt. And as the refiners select for their purposes sugars of a dry, gritty, crystalline grain, as little discolored and moistened by molasses as possible, it follows that the proportion of foreign matter which they have to extract is comparatively small.

2. Hence, in refining, the operation of defecation is far less difficult than in the manufacture of the raw article. Under the old method of refining by means of bullock's blood, there is, indeed, nothing particularly worthy of notice except the action of the lime-water in which the sugar is dissolved; for the operation of the blood is simply mechanical, collecting together, in a kind of net-work, all solid, swimming particles, by the coagulation of the serum or albumen, and which may therefore be considered as a sort of straining or filtration; but the lime-water, which is by the refiners supposed to act simply as a base to neutralize acid in sugars, has quite a different part to play. In moist sugars, (the molasses in which has undergone partial fermentation, giving rise to the formation of a small quantity of alcohol, which, by absorbing oxygen, passes into acetic acid,) doubtless the lime-water neutralizes this slight quantity of acid. But this lime acts chiefly on the albumen of the molasses and the sugar, aiding in the coagulation of a portion of the albumen, combining with and rendering soluble another portion thereof, and uniting chemically both with the grape sugar (*saccharo-glucose*) of the molasses and a portion of the cane sugar itself. Although, after this union with lime, sugar may perhaps be somewhat less injured by heat, still it cannot be doubted that the soluble and uncrystallizable compound thus formed of sugar and lime involves considerable loss, inasmuch as the lime is united in it with twice its weight of sugar. The lime also gives a dark color to the grape sugar, and we may conclude that, if the subsequent operation of claying were omitted, sugar of a quality inferior even to that of the raw material would be obtained. But, by means of the combination of a portion of the sugar with the lime, the crystallization is of looser and larger grain; thus favoring the removal, by displacement with water in claying, of the intervening impure sirup and other foreign matter.

3. In the modern process of refining, great improvements have taken place in defecation by the use of animal charcoal. In 1811, M. Figuier, of Montpelier, discovered, and in 1812 M. Dérosne recommended, the substitution of pulverized bone or ivoryblack as a more energetic substance for wood charcoal, which (in 1805) had been introduced and employed by M. Guillon to clarify and decolorize sirups. The boneblack is added to the hot solution of sugar in quantities not exceeding 5 or 10 per cent. of the sugar. Considerable effervescence takes place by the escape of gases condensed in its pores, or by the disengagement of carbonic acid from the carbonate of lime contained in the boneblack, the lime of which unites with and neutralizes the acetic acid which has been formed by fermentation in the sugar. Hence, with good dry sugars there is little or no necessity for the addition of lime. For very moist sugars, however, a quantity of lime water may be used advantageously, and any slight excess of lime will be removed by the boneblack.

4. Muscovado sugars usually part with their coloring matter and

mineral impurities by the use of boneblack far more readily than with a sort of mucilage or pectine, which they usually contain in small proportion, and which renders the decolorized sirup opalescent, or only imperfectly clear. Hence most refiners, by the new and improved methods, still continue to use a small quantity of blood to render their sirups transparent. To obviate this difficulty, or the necessity of using a substance so offensive as bullock's blood, various articles have been tried, such as alum, acetate of lead, &c.; the objection to which has been chiefly that they may leave in the sugar soluble salts, or other foreign matter. Such impurities are readily detected by means of chemical tests.

5. In this connexion it gives me pleasure, as an act of justice, to bear testimony to the purity of those sugars, refined by the large establishments in the United States, which I have analyzed, and especially the manufactures of the Boston sugar refinery, Woolsey & Woolsey, R. & L. Stewart, of New York, J. S. Lovering & Co., of Philadelphia, and Mr. Richstein, of Baltimore.

I have heard it charged that some of these refineries employ alum to impart beauty of crystal to their sugar, by being mixed therewith—an allegation alike untrue and absurd. I have visited them all, and carefully inspected the operations therein performed, (except at the refinery of Woolsey & Woolsey,) and I speak from personal knowledge, therefore, in what I have said.

In the refinery of J. S. Lovering & Co., a process is employed for clarification peculiar, I believe, to that establishment, which has been communicated to me confidentially, and which I consider perfectly unexceptionable; neither alum, bullock's blood, nor any other objectionable substance being there used for clarification in making sugar absolutely pure and of extreme whiteness and beauty.

6. In 1812, Mr. Howard, the inventor of the celebrated vacuum pan, patented a method of defecation by means of a substance known as Howard's *finings*. For every hundred weight of sugar to be refined, 2½ pounds of alum are dissolved in about 24 times its weight of water, and three ounces of whiting are then added, stirring the mixture until it ceases to effervesce. When it has subsided, the supernatant liquor is decanted, and the precipitate is well mixed with such a proportion of cream of lime as to cause it barely to stain tumeric paper when wet, but which shall be restored to its yellow color on drying. The cream of lime is prepared by slaking quicklime, and making it into a thin paste with water, which is boiled until the lime appears like curdled milk, and then passed through a fine sieve.

Of the value of Howard's finings I cannot speak positively, but at present they are, I believe, little used by refiners. By the reaction of the whiting (carbonate of lime) upon the alum, sulphate of lime, alumina, and sulphate of potash are produced. The latter being soluble in water, would be dissolved in the sirup; hence the necessity that the precipitate be well washed. If the sulphate of potash be carefully removed, by washing, from the alumina and

sulphate of lime, the mixture of the two latter might, I believe, be advantageously employed with fine boneblack for defecation, but in small quantity only, and not in such large proportion as recommended by Mr. Howard.

7. Alum alone has been tried by some refiners. It is mixed with the solution of sugar; and after it is well diffused, lime is added, as usual; sulphate of lime and alumina precipitate, and act like coagulated albumen, mechanically, to clear the solution. But sulphate of potash would remain in solution; and, if considerable in quantity, must injure the sugar.

8. *Defecation of the juice of the beet.* To understand the theory of the defecation of beet juice, a knowledge of its chemical constitution is essential. This has been made a subject of investigation by several distinguished chemists, and may be considered, therefore, as well known as in the present state of chemical science is readily practicable. But future progress in chemistry may, and doubtless will, cast new light upon this matter.

Of all the analyses which have been made, I give as perhaps the most complete the following, made by M. Braconnot:*

The Silesian beet contains—

1. Crystallizable sugar;
2. Uncryssallizable sugar;
3. Albumen;
4. Pectine;
5. Mucilaginous matter;
6. Lignin;
7. Phosphate of Magnesia;
8. Oxalate of potash;
9. Malate of potash;
10. Phosphate of lime;
11. Oxalate of lime;
12. A fatty acid of the consistence of tallow;
13. Matter analagous to wax;
14. Chloride of potassium;
15. Sulphate of potash;
16. Nitrate of potash;
17. Oxide of iron;
18. Nitrogenous matter, soluble in water;
19. An unknown odorous and acrid substance;
20. An undetermined salt of ammonia, in small quantity;
21. Pectic acid.

9. The crystallizable sugar usually constitutes about five to ten per cent. It gradually increases as the beet advances; but if allowed to run to seed, no sugar will be found in the juice. In such

*Ann. de Chim. et de Phys., t. lxxii, p. 444.

a beet, M. Péligot could not detect even a trace of sugar; in beet leaves he found but a very small quantity.

10. The existence of uncrystallizable sugar already formed in beets is a disputed point; while, as by the above analysis, M. Braconnot admits it, Messrs. Pélouze and Péligot, chemists of equal rank, were unable to extract it by alcohol. Certainly, therefore, it exists, if at all, only in such proportion as to be practically inappreciable.

11. The *albumen* contained in the beets appears to be in the fluid state, and is expressed with its juice. As it is thus in the soluble form, it also is extracted by the processes of maceration. According to M. Braconnot, the presence of a free acid in the juice prevents this albumen from being coagulated by heat alone. Hence the employment of lime, by neutralizing that acid, coagulates it. It is also coagulated by sulphuric and other acids, as well as by certain salts, such as acetate of lead, sulphate of zinc, &c. By incineration, M. Braconnot found that the albumen yielded carbonate and phosphate of lime. In what manner or form the lime of this carbonate of lime exists in combination with the albumen, it is difficult to imagine, and the subject requires further investigation.

12. The *pectine*, according to M. Braconnot, remains in the pulp when submitted to pressure, and is not found in the expressed juice. Cold water dissolves the sugar, the albumen, and the soluble salts, but leaves the pectine, which may then be extracted from the *lignin* (woody fibre) by hot water, and forms a viscid solution. Neither acids, the salts of lime, nor tannin, produce any apparent effect upon this solution, but slacked lime causes it to coagulate.

13. The *mucilaginous matter* which M. Braconnot gives as a constituent of beets, analagous to gum, is perhaps a modification of pectine. So, likewise, the *pectic acid* which he obtained is supposed by other chemists not to be contained in the beet, but to result from a species of fermentation of the pectine.

14. The *lignin*, or woody fibre, though contained in all, yet varies with the age of beets, being greater for those which are very young or very old. It contains oxalate of lime and the phosphate of lime and magnesia; the latter is soluble in acids, from which it is separated by bases. The expressed juice also contains phosphate of magnesia, together with all the soluble salts above mentioned. The *fatty acid*, of the consistence of tallow, appears, according to the analysis of M. Dubrunfaut, to be composed of a fixed oil and a solid fat.

15. Besides the above-mentioned substances which are contained in the white beet of Silesia, there are in red and yellow beets co-

loring matters which impart to them their respective colors; which colors are easily removed by boneblack.

As results of chemical change or fermentation, beet juice may also contain uncrystallizable sugar, a brown coloring matter, and a viscid substance which is insoluble in water. The nature of the soil in which they are planted also changes greatly the composition of beets, and especially of the salts, both in their kind and proportion.

16. The following results, obtained by M. Péligot, will enable the reader to form an idea of the relative proportions of the constituent substances contained in beets of different ages:

| Description of beet. | Weight in grammes. | Per cent. of constituents. | | | | |
|---|---|---|---|---|---|---|
| | | Water. | Sugar. | Pectine. | Lignin and albumen. | Nitre. |
| From the botanical school, Aug. 2.. | 20 to 25 | 90.5 | 5.0 | | | |
| Do .....do.....Sept. 7.. | 800 to 900 | 90.0 | 7.3 | 0.8 | 1.9 | |
| Do .....do.....Sept. 26. | 80 to 100 | 84.9 | 10.0 | 1.8 | 2.3 | |
| Very young..... | 0.285 | 86.3 | 5.9 | 3.4 | 4.4 | |
| In flower..... | 200 | 83.5 | 9.8 | 3.4 | 3.3 | |
| In seed, second year..... | ..... | 94.5 | 0.0 | 1.1 | 2.5 | 1.9 |
| Beet leaves..... | ..... | 93.6 | 1.3 | | 3.6 | 1.5 |

17. As the composition of the beet varies with age and soil, so also does it vary with drought or wetness of season. M. de Dombasle has observed that the density of the juice increases in dry weather, and decreases when the ground is saturated by rain. This variation of density amounts to from one to two degrees Beaumé: it is greatest in sandy and least in clayey soil; the latter retaining moisture longer and absorbing it less rapidly than the former.

The preceding facts will be sufficient to permit us to form correct ideas of the chemical reactions which are concerned in the process of defecation. We should bear in mind that besides water and sugar, the principal constituents of the beet are pectine, albumen, and woody fibre, while the saline and other impurities exist in comparatively small quantities. Hence we may disregard the latter, except in so far as they exert an influence upon the former by modifying the chemical phenomena. Thus, for instance, it appears, as above mentioned, that the albumen in beet juice cannot be coagulated by heat alone, in consequence, perhaps, of a free acid.

We should also take into consideration the effects produced by the different methods employed for extracting the juice. When the process of rasping and pressing has been employed, the expressed juice will contain sugar, albumen, and the soluble salts,

those of potash and ammonia, together with the nitrogenous substance No. 18; while the pulp will consist of woody fire, retained juice, the insoluble salts, and the greater part of the pectine. Owing, however, probably to mechanical causes, a small portion of the pectine escapes with the juice. When maceration in cold water is used, the saccharine solution will contain the same impurities, with the exception of pectine. Maceration in hot water extracts most of the pectine and all the substances soluble in cold water, except part of the albumen; the pulp retaining the insoluble substances and the rest of the albumen and pectine.

18. Two methods of defacation have generally been followed in the beet sugar industry; in one of which, the older, both sulphuric acid and lime are used; in the other, lime alone is employed. The latter seems to be much the preferable method.

When sulphuric acid is used, 1 part by weight thereof, at the usual strength of 66° Beaumé, is diluted with 8 parts of water, and added to 2,000 parts of expressed juice, in wooden tanks holding each about 175 gallons, and lined with lead, and into which the juice flows by troughs from the press. In these tanks the juice is often allowed to stand a considerable time; and from them it is removed to the defecators, vessels of about the same capacity of 175 gallons, with double bottoms, that they may be heated by steam; for a more particular description of which, see plate 1, figure 7. In defecators, lime is added usually in the proportion of about 1.25 of the weight of sulphuric acid, and which has been slacked and mixed with water into a cream of lime. Heat being applied, the liquor is well stirred; and when it has attained the temperature of about 100° Fahrenheit, one or two gallons of bullock's blood or skimmed milk are poured in. As soon as it commences to boil, or at 212° Fahrenheit, the heat is checked entirely. The scum is removed from the surface, and subjected to pressure to extract the juice it may have absorbed; and the defecated liquor is allowed to repose for a few minutes, that it may become clear.

19. In the method of defecation by lime alone, this agent is employed in proportions from 2 to 12 thousandths of the weight of the juice, according to its nature, which varies, as above described, with the kind of beet, the soil, the wetness or dryness of season, &c. The quantity of lime to be used is ascertained by trial or by experiment, though very roughly. The juice flows from the press into defecators similar, both in size and form, to those described above; and when it is heated to about 140° Fahrenheit, the lime is added, mixed with water into a paste. The mixture is stirred thoroughly for a few moments, and then permitted to remain undisturbed until the first appearance of ebullition, when the heat is shut off, the scum removed to be pressed, and the liquor left to repose, that solid particles may separate as scum or by precipitation.

20. The action of lime on beet juice is somewhat complicated.

1st, it coagulates a portion of the albumen; 2d, it unites with and renders soluble another portion thereof; 3d, it converts the pectine into pectic acid, with which it combines; 4th, it decomposes some of the soluble salts; 5th, it forms with sugar a soluble chemical compound, saccharate of lime; 6th, it saturates any free acid which may exist. Hence it is not at all surprising that great difficulties attended the use of lime in the earlier attempts, and that Achard, of Berlin, to whom the beet sugar industry owes its origin, should have even preferred sulphuric acid as a defecating agent.

Sulphuric acid coagulates the albumen contained in the beet juice very promptly; but if its action be continued, it converts the cane sugar into left polarizing sugar, which cannot be crystallized. This effect takes place very quickly when aided by heat; and if the acid remain unsaturated, it may, in evaporation, even carbonize a portion of the sugar.

21. Thus neither sulphuric acid nor lime can be used alone, *in excess*, without injury. The first attempts at making beet sugar were, therefore, attended with but little success; a dirty black mass being often produced, instead of good crystalline sugar. Subsequently, the use of sulphuric acid, followed by the addition of lime, as above described, enabled the beet sugar makers to produce a much better article and with greater certainty; but this method, which has since been to a great extent abandoned in consequence of the introduction of boneblack, was attended with the disadvantage of requiring very great skill to neutralize the acid without leaving an excess either of acid or of lime to produce injury. Besides, the acid could not often be neutralized before it had converted a considerable portion of crystallizable into uncrystallizable sugar.

22. Since boneblack has been employed for filtration and decolorization, slight excess of lime in defecation has been attended with no injury; and, consequently, lime alone has been used, according to the method above described. The manner in which the boneblack acts thus as a remedy for an over-dose of lime depends upon the presence of a small portion of carbonate of ammonia, which is decomposed by the lime forming carbonate of lime and setting the ammonia free. This ammonia is subsequently volatilized and driven off by the heat in the process of evaporating the juice; but, to render the use of boneblack sufficiently economical, the lime thus acted upon by the carbonate of ammonia must be in small quantity—a condition of great importance, and which requires that it be used very nearly in the exact proportion necessary to coagulate the albumen and separate the other substances with which the lime forms insoluble compounds, without leaving any considerable residue to dissolve albumen and unite with sugar, to constitute soluble saccharate of lime. In short, the quantity of lime must be either exactly that of perfect defecation, or very little in excess—a nice point, to attain which requires some skill and care.

23. By some manufacturers the lime is added by weight; by others it is mixed with water into a paste, of such consistence as to indicate about 14° Beaumé, and then used by volume or measure. It is not very convenient or easy to weigh each time exactly, and in small quantities, the lime required, without balances and weights of better construction than those commonly employed in the arts. Hence it has been generally preferred to mix it into a paste with water, and in large quantity, so as to have on hand a considerable supply of uniform quality. When the lime contains silex—as most lime does which is manufactured from ordinary limestone—the method of using it in the form of paste has the further advantage of being freed somewhat from the silex, which precipitates. As neither the appearance nor the density of the juice furnishes an indication of the quantity of lime to be employed for defecation, experiments on a small scale must be made. The following method of performing these experiments, suggested by M. Payen,* seems to me to be attended with simplicity, convenience, and, what is of great consequence, despatch: prepare, by weighing beforehand (in a small pair of scales, such as are used for medicines,) six doses of slacked lime, of one gramme (15 grains) each; or, which is better, six equal measures of paste of slacked lime, marking 13° or 14° Beaumé, and containing one gramme each. Then heat in any convenient vessel one litre, or any other definite measure—for instance, one quart—of beet juice; and, when it has reached the temperature of 125° to 150° Fahrenheit, add one dose of the lime, mixed with water; and as soon as it commences to boil, take out a spoonful of the liquid and pour it into a paper filter, placed in a funnel. Add then a second dose; put the juice again on the fire, and when it begins to boil take another spoonful, which filter as the first. Continue this operation until the whole six doses have been added.

The liquid filtered from each spoonful is caught in a glass tube, and the six tubes permit the results to be compared very accurately by looking through them lengthwise. The first tube, which shows a clear amber-colored liquid, indicates the proportion of lime to be used; for although the following tubes contain clear liquids, equally or even more colorless, the excess of lime in them will be injurious.

It is important that the lime used in defecation should be as minutely divided as possible. To this end it should be carefully selected, if practicable, of the best quality; and not only slacked in considerable quantities, but thoroughly mixed into a smooth paste by stirring it gently for some time. By allowing it to subside, and then removing the clear water from it by decantation, it will be improved, if it contain potash or any other soluble salt; and this washing may even be repeated several times with advantage.

Though the experiments upon a small scale, above described, are very useful to determine approximatively the dose of lime to be used in defecation, they yet require to be checked by the results of working on the large scale. Nor will they answer for an entire

* Cours de Chimie Industrielle, vol. 2.

crop, but must be from week to week repeated, if the manufacturer has reason to suppose that the juice varies, by reason of any difference of circumstances in the culture or growth of the beets.

24. It is therefore important that the characteristic indications of a good defecation should be practically and familiarly known. They are—"1st, an escape of ammonia, very sensible near the surface; 2d, a distinct separation of flakes, swimming in clear juice, and easily seen in a silver spoon; 3d, an iridescent or rainbow-colored pellicle, which forms when the breath is blown upon the liquor; 4th, a moist greenish scum, forming thicker and thicker on the surface, and then becoming of the consistence of curds of milk or fresh cheese; 5th, crevices taking place in the thickness of the scum; 6th, the first irruption of juice through one of the crevices, indicating the commencement of ebullition."*

25. Hence it appears that defecation consists in a proper coagulation of the albumen, and consequent separation of the insoluble matters, as in the operation of clarifying with bullock's blood in refining; and that the heat must be checked at the instant of ebullition, to prevent the impurities collected by the coagulated albumen, as a net-work, being disturbed and mixed again with the juice.

When an excess of lime has been used, the above described indications all appear; but the clear juice retains a disagreeable taste, which is only partially removed by filtration through 3 or 4 per cent. of boneblack in grains. But if lime be employed in great excess, the scum is soft and pasty. Some manufacturers put a portion of the clear juice into a glass, and blow their breath through it with a straw or tube; it then losses its limpidity and becomes turbid, if it contain an excess of lime, by forming carbonate of lime with the carbonic acid of the breath. The albumen, which is coagulated by lime in proper proportion, is dissolved gradually as the excess of lime becomes greater. The scum, therefore, which should be firm, coherent, and dark colored, even almost black sometimes, and which should crack so as to allow the clear juice to be seen, becomes soft and of a yellowish color when much lime is used.

The preceding description and discussion of the process of defecation of beet juice extracted by the usual method of rasping and pressure, is equally applicable to the same operation as performed upon the solution of that juice obtained by the process of maceration in cold water, and which solution is, chemically, similar to the expressed juice. But when the process of maceration in hot water is employed, a solution is formed which contains, as already stated, a small proportion of albumen, but a large quantity of pectine; defecation then becomes extremely difficult, for the feculencies are soft, and do not collect readily into a scum. They of course consist chiefly of pectate of lime, with a small and insufficient quantity of coagulated albumen. Owing to this trouble, and

* Payen. Cours de Chimie Industrielle, vol. 2.

also to the disadvantage that warm aqueous solutions of beet juice are very apt to ferment, maceration in hot water has been generally abandoned by those who have attempted it; and consequently the knowledge of the chemical phenomena which occur in the defecation of such solutions is very limited and unsatisfactory.

26. Attempts have been made to substitute other substances for the lime and sulphuric acid used in the defecation of beet juice. Of these, sulphate of lime (plaster-of-Paris) has been strongly recommended by M. Braconnot, but it has not been sufficiently tried on a large scale to permit a just opinion to be formed of its value for such a purpose. Sulphate of zinc defecates readily, but its use is attended with great danger, being poisonous in large and an emetic in small quantity. So also sugar of lead defecates well, but is a violent poison. Such substances, therefore, cannot be used with any propriety. Common alum seems, however, to have given favorable results if employed in small quantity, and in connexion with lime.

27. Very lately, much has been said in France of a process followed by M. Bouché, by which he has been enabled to make white sugar equal to refined directly from beet juice. Part of this process is defecation with alum and lime, which is thought to be a great improvement; for, by diminishing the quantity of lime used, it prevents the injurious effects and the disagreeable taste caused by the lime. M. Bouché employs a solution of alum, in the proportion of one and a half grammes (22.5 grains) of alum to each litre (1.75 pint) of beet juice. He pours it into the boiler as soon as the juice has attained a temperature of 100° or 105° Fahrenheit, stirs thoroughly and briskly, and continues to heat the liquor until it reaches the temperature of 175° or 180 Fahrenheit. A small quantity of cream of lime is then added, and the mixture well stirred. When ebullition commences, the fire is checked; and after a repose of five minutes, a dense, firm scum is removed.

28. The mode of extracting the juice absorbed by and removed with the scum in skimming the defecators is to submit it to pressure in a lever press, (see plate 1, fig. 6;) which is not only the simplest kind of press which could be made, but also the most convenient, as it acts constantly and does its work without requiring any attention after supplying it with material. The juice thus saved is mixed with the rest of the defecated liquor.

If by the above described operation, called by the beet-sugar makers *defecation*, the end designed were perfectly attained, to wit, the complete separation from beet juice of all impurities or feculencies, then nothing would remain to be done to obtain the sugar properly but to filter, decolorize, and evaporate the juice.

So obstinately, however, does beet juice retain or combine with its impurities, that even after defecation it is still requisite to separate much from it. To do this a further operation is usually performed, which has received the name of *clarification*.

Although *defccation* and *clarification* have but a single object, to separate the impurities combined with beet juice, and therefore constitute and may be considered one operation, if we regard only the chemical effect produced; still, as they are performed separately, and upon the same juice at different times and degrees of density, clarification even being preceeded in the order of the manipulations by filtrations and partial evaporation, they are usually treated of in works on the manufacture of beet sugar as entirely distinct operations. Chemically they are one, though mechanically two. In the art of refining sugar, they are usually confused together under the single name of clarification. In the manufacture of cane sugar, defecation only is practised. Hence I have seen fit to comprise these two operations under one head or division of the general subject of the sugar industry.

Great diversity of practice exists among beet-sugar makers with reference to the operations succeeding that of defecation. Filtration, for instance, is generally performed two or three successive times; a few, however, do it but once. Some filter immediately after defecation; others at 10°, 15°, or 27° Beaumé. Some use filters of cotton cloth; others filters of coarsely divided boneblack; the most general order or routine of operations being defecation, filtration, evaporation to 15° Beaumé; 2d filtration, evaporation to 27° Beaumé, clarification; 3d filtration, concentration; by which it appears that if we would classify the operations, and treat of those together which are similar, we must violate somewhat the order in which they usually succeed each other in performance.

29. *Clarification.*—However perfectly the *defecation* may be performed and however limpid the filtered juice may become, it still contains dissolved compounds of lime, which separate as insoluble matter during the evaporation by heat to which the juice has to be subjected. We cannot account for this by supposing the precipitated matter to have been simply held in solution by the evaporated water, for it is not dissolved again by restoring the water. Nor is the hypothesis satisfactory which has been suggested, that in evaporation new combinations take place, which become insoluble by the force of cohesion. Obscure as the chemical theory of this separation may be, the fact is nevertheless unquestionable. In consequence of it, the concentrated juice is mixed with fine insoluble particles, which must be removed either by filtration or clarification; for they would require a long time to subside if left simply to repose.

30. The operation of clarification is performed usually as follows: bullock's blood, in quantity equal to about one half of one per cent. of the concentrated sirup by measure, is thoroughly stirred into the sirup, which weighs 27° or 32° Beaumé, so as to diffuse the albumen of the blood uniformly through the whole; from one to two kilogrammes per hectolitre of sirup (one to two pounds for ten gallons) of fine animal charcoal are then added; and heat being applied, the mixture is stirred until it attains the

temperature of 130° to 140° Fahr.; the stirring then ceases. If the heat is properly managed, the albumen soon coagulates and rises to the top as a scum, bringing with it the boneblack. When ebullition commences, the heat is checked. The liquor will be perfectly clear if neither alkaline nor acid. If lime has been used in excess, it will be alkaline; and if fermentation has taken place, it may be acid. In either of these events, albumen will remain in solution, and will render the sirup impure. An acid liquor should never be clarified without first neutralizing the acid with lime; and therefore the sirup should always be tested beforehand with litmus paper, to ascertain whether it be perfectly neutral. The albumen which is dissolved by an alkaline sirup separates as a scum in the subsequent concentration and granulation.

After the introduction of Dumont's filters, and the use of coarse granular boneblack as an agent not only of filtration, but also of decolorization and purification, most of the manufacturers of beet sugar abandoned the process of *clarification*. But many have resumed it; for the reason that, when sirups refuse to granulate, fine boneblack causes them to do so. Coarse boneblack would produce the same effect, but it must be used in great quantity; while a very small quantity of fine boneblack answers the purpose, the reason of which is not understood. Besides, the fine boneblack (being supplied by sifting the coarse in revivification) would be a refuse article, unless used for clarification; and its employment is therefore economical.

Some manufacturers of beet sugar employ milk instead of blood for clarification. But as heat alone does not cause milk to coagulate, the sirup must either be rendered alkaline by lime, or slightly acid by dilute sulphuric acid, to obtain a proper clarification; neither of which agents can be employed without injury to the sugar.

31. *Defecation of cane juice.* While the beet-sugar industry has had great difficulties to contend with in the very impure nature of the juice employed, it yet has received in France every facility and advantage which the science, intelligence, and fostering care of a powerful and enterprising nation could afford. On the other hand, the cultivation of the cane, and the art of extracting sugar from it, seem almost to have been left for centuries to the management of the ignorant and stupid negro. Nature, however, in the abundant growth of tropical climates, and a juice of great comparative purity and richness, favors the cane with advantages which more than compensate for the rudeness of the processes followed. Thus, in these two similar and rival industries, we behold science overcoming obstacles imposed by nature, and contending with indolence favored in every respect; so successfully, also, that of late years the French government has seen fit to remove the privilege of exemption, and to tax the manufacture of beet sugar, thereby placing it on an equality with their colonial sugars paying duty.

In nothing, perhaps, is the contrast between the beet and the cane sugar manufactures more striking than in the operation of

defecation, as performed usually in each. Caution, care, and skill distinguish the one; while carelessness and mismanagement pervade the other. Essentially a chemical process, and therefore requiring some knowledge of the composition and properties of cane juice for its correct and intelligent performance, little or nothing can or should be expected if it be left entirely to the care of negroes or of ignorant white men. Some of the more intelligent planters, however, superintend and direct in person the operations of the sugar-house; a practice which, though laborious, especially at night, is yet often indispensable if they would look properly to their own interests.

32. Lime is generally the only agent of defecation employed. Care should be taken that it be used neither in excess nor in deficiency. But to determine the proper quantity, experiments on a small scale are tried only by a few; the results of working being generally the means of judging whether the amount employed at any time was correct. A practice so loose is of course attended with constant uncertainty and frequent injury to the sugar.

To measure the quantity of slacked lime for defecation, a small wooden box or trough is used by some; it is one foot in length, and four inches both in height and breadth, being divided from inch to inch by grooves, into which a slide slips. Each division therefore corresponds to sixteen cubic inches. Rough as the above contrivance is, it has the advantage of rapid measurement, and even for accuracy is infinitely preferable to the rough scales and weights sold in the shops.

The proper dose of lime varies with the nature of the cane and the country; juice from perfect canes requiring less than that of immature, or such as are otherwise of inferior quality.

In Louisiana and the French islands, the juice is permitted to flow from the mills into large shallow wooden tanks, or receivers; the pieces of cane trash, and other mechanical impurities, being separated in part from it by passing through sieves. In these receivers it is allowed to stand quietly for a while, and it is then drawn off carefully, so as to leave in the receiver the dirt which may have separated from it, either as a scum or by precipitation. It passes to the first and largest evaporating pan, called the *grande*, where it receives the lime intended for defecation, and is heated until the thick scum which rises to the surface cracks, and ebullition is about to take place. The scum is then removed by skimming, and the juice is rapidly dipped out with large copper ladles, and poured into the next pan, or boiler, called the *flambeau*. The lime is introduced by first mixing it into a thin paste with two or three gallons of the juice.

If the juice thus defecated be light colored and transparent, and readily throws up in the flambeau the remaining feculencies which are mixed with it, the operation is supposed to have been properly performed. But if the juice be dark colored, has a disagreeable alkaline flavor, and boils in a peculiar manner, the lime is supposed to be in excess; while slimy feculencies adhering to the

pan, &c., indicate deficiency. The feculencies which separate in the *flambeau* are carefully and incessantly removed by skimming them back into the *grande*, and the scum which was taken from the latter is thrown away, the clear juice which drained from it being added to the next charge. If lime has not been used in sufficient quantity at first, it is added in the *flambeau*.

33. In the islands of Cuba and Jamaica the practice is somewhat different, and probably preferable. The juice flows from the mill into large wooden tanks, as in Louisiana, but passes from these into the "clarifiers," "racking coppers," or "cracking coppers," as they are variously called. These clarifiers are large rectangular and shallow copper vessels, about ten feet or more in length, five or six feet in breadth, and about twenty inches in depth, usually placed over the flue of the furnace, that the heated air and fumes may, before passing up the chimney, heat the juice in the clarifier, but never to the temperature of boiling, or 212° Fahrenheit. Trains of pans so arranged with clarifiers are usually known as Jamaica trains. As one fire is made to answer successively for four evaporating pans, and the furnace is so constructed as to concentrate the heat upon them, it follows that it is only the waste-heat which supplies the clarifiers, and consequently that their use is attended with economy of fuel. Besides, as the juice is allowed to stand quietly in them for a time, and the feculencies to collect together, after which the clear liquor is drawn off carefully by means of a syphon, or stopcock, it is thought that the employment of clarifiers may be attended with the advantage of a more perfect separation of the feculencies than can be produced if the operation of defecation be performed in the *grande*, in which the juice often boils before the scum is removed, causing the feculencies to be dispersed somewhat through the liquor.

Yet it is very questionable whether vessels so shallow as the clarifiers admit of decantation of clear liquids from feculencies so light as those of the cane juice without even more admixture of feculencies than ever occurs in the French mode of defecating in the *grande*, from the cause above mentioned. Considered, however, as mere receivers, or tanks, in which the juice is kept for a while, and allowed to clarify in part, if not perfectly, so as to lessen the amount of impurities to be removed in the *grande*, these clarifiers are certainly very useful appendages to the train of evaporating pans; for the heat, while it removes a large portion of the feculencies by coagulating much of the albumen, is also usually sufficiently high (about 150° to 180° Fahrenheit) to check or prevent fermentation.

If, instead of vessels of large surface and but little depth—a shape usually adopted, I presume, to permit of more extended application of the heat of the flue—cylindrical vessels of considerable depth and less diameter were substituted, these would permit the clear liquid to be drawn off, and the scum to be removed by skimming, with great readiness; they could not, however, be heated in the same manner as those in use.

34. The lime is added by some in the clarifiers; by others, only in the *grande* or first *teache*, as it is called in the English colonies; and by others, in both; while some even put it into all the pans or teaches, except the *battery* or *striking teache*. In Jamaica, the dose of lime employed was formerly, according to Bryan Edwards, about a pint in powder, after slacking, to a hundred gallons. Of late years it is stated to have been reduced nearly to one-third of that quantity, and with decided improvement to the sugar manufactured. In Cuba, the amount of lime used for defecation varies even from day to day, with the caprice of the ignorant Spanish sugar boilers usually employed; and this delicate point, which requires so much care and skill, would be perhaps almost as well performed as by them, if lime were scattered about the sugar pans, and allowed to be blown into them by the winds.

Of late years, separate clarifiers heated by steam, have been used both in the West Indies and Louisiana; those in the islands are generally defecators, copied closely after those employed in the beet sugar works of France, and which therefore need no further description or discussion. In Louisiana, a less costly apparatus has been tried; with what succes, I am not informed. It consists of a wooden reservoir or vat, lined with lead or copper, and heated by means of a steam-pipe. The juice being heated in these vats to 212° Fahrenheit, is allowed to remain quiet for a while, that the feculencies may collect, when it is drawn off by cocks, through a cloth filter, into a reservoir or into the *grande* itself. Although the advantages of using steam are great, I should be inclined, in the absence of information with respect to actual results, to consider these wooden clarifiers liable to two great objections: first, that they cannot be readily cleaned; and, secondly, that it is found extremely difficult and even almost impracticable in the arts to make vessels lined with metal and soldered together which will remain perfectly tight if subjected to frequent and great changes of temperature, and especially such as are connected with steam-pipes. The expansion and contraction of the metal loosens the solder, and thus causes them to leak.

35. In Jamaica, a small quantity of a solution of alum is often used to correct the effects which result from an over-dose of lime. Thus employed, there can be no important objection to the use of alum; for, while it leaves in solution a small quantity of sulphate of potash, a salt which is inoffensive, it abstracts the excess of lime and the feculencies which were united with it, and thus renders them soluble. The carbonate of potash, in the form of lye, is said to be extensively used in Brazil; and the clayed sugars imported from that country are considered inferior to Havana sugars, by reason of the injurious effects of the potash. It has even been stated to me that these sugars contain potash in sufficient quantity to render the mouth sore if they be employed for household purposes; but I must confess that neither I, nor others to whom I have submitted specimens for chemical analysis, were able to detect in them any excess of potash; and I therefore doubt whether Brazil

sugars are as alkaline as has been represented. That they are moist and very inferior grain is, however, undeniable. In Louisiana, potash or lye is sometimes employed for the defecation of frosted cane juice; but such juice, it is said, becomes clarified by heat alone, and if so, the use of potash is not only unnecessary, but improper; for that potash renders sugar deliquescent or moist, seems to be the result of long and extensive experience. Under the head of potash we should also place the ashes of certain plants, to which, at various times and different places, peculiar efficacy as defecating agents has been ascribed, inasmuch as they owe their influence to the potash they contain.

In the improved method of M. Dutrone for the manufacture of sugar—at which he arrived after long study, and many experiments upon a large scale, in the island of St. Domingo, before the massacre of its civilized inhabitants—he adopted and recommends the cautious employment of very dilute sulphuric acid, or of cream of tartar, to neutralize the lime which has been added in excess.* And thus he anticipated the practice of the beet-sugar makers of France of a succeeding generation.

At the time of Dutrone, the applications of steam to the arts, and especially of high steam, were comparatively unknown; the useful properties of boneblack had not been discovered, and the science of chemistry had made little progress, for it had just commenced to be an exact science, in consequence of the researches of Lavoisier and his contemporaries. If we bear the fact just mentioned in mind, the celebrated work of Dutrone certainly will appear to be the most able treatise ever written on the culture and manufacture of sugar. It is a book which may be read with profit by every planter: in it he will find the errors of the usual process of making sugar, which to this day remain unchanged, clearly and forcibly discussed; though the chemistry of Dutrone is often in error, and is generally expressed in language which now appears quaint. This work in the French language has become rare; but, in the English language, Mr. Porter has furnished a book,† much of which is copied from that of Dutrone. Had Dutrone lived at the present time he would not, however, have considered his own method the perfection of the art of sugar-making. The use of steam and of boneblack would have been regarded by him as indispensable improvements; nor would he have caused to be printed and published, in the face of modern science, the chemical errors and obsolete phraseology to which his commentator has unwisely, in my opinion, seen fit to adhere.

36. Of late years, some of the planters who have availed themselves of the great advantages afforded by the use of steam for heating, and by evaporation in vacuo, have also employed boneblack for decolorization and clarification. They have generally

*See Dutrone, Precis sur la Canne, et sur les Moyens d'en extraire le Sel Essentiel, page 163: Paris, 1790; also Porter on the Sugar-cane, page 109: London, 1843.

† The Nature and Properties of the Sugar-cane, by George Richardson Porter, F. R. S. corresponding member of the Institute of France, 2d edition: London, 1843.

employed it only in the coarse, granular form, and in Dumont's filters, as described in the sequl of this report. In Louisiana, on the estate of Messrs. Packwood & Benjamin, the use of boneblack filters has been thoroughly tested, and with entire success. I mention this fact particularly, because I have been told that some very intelligent planters of that State have expressed the opinion that Louisiana cane juice cannot be filtered readily through boneblack, by reason of the mucilage it contains.*

In the principal West India islands, French, Spanish, and English, on estates which have adopted apparatus for boiling in vacuo, boneblack has also been used. In the French and Spanish islands the apparatus and method employed are generally those of M. Derosne. The juice being defecated with lime, is then filtered through boneblack, which removes the excess of lime and other impurities of the juice. The defecators are precisely similar to those used in France, and the method of manufacture analogous to that of the beet-sugar industry, only it is far simpler. The juice, owing to its purity, is filtered but twice through the boneblack; and it is then ready to be evaporated to granulation. In Cuba, Messrs. Diago and Ayestaran have employed the method of Derosne with great success and profit. On their estate near Guines, (the *Ingenio la Amistad*,) not only their own crops have been by them manufactured entirely into *florete* white and yellow sugars, but they have purchased the inferior sugars of their neighbors, and refined them into such as their own. The specimens of sugar I obtained and saw manufactured on that estate, directly from cane juice, are equal to the best single-refined of the United States, in every respect. But these results, so admirable, are certainly to be ascribed in a very great measure, if not chiefly, to the excellent management of the owners, who are not only gentlemen of ample fortune, but of uncommon enterprise and intelligence. For, on the estate of Don Villa Urutia, near Limonar, the adoption of Derosne's apparatus has been attended with great misfortune and loss; which, I have been informed, was probably owing to want of knowledge and skill in the management of the boneblack.

So important is the article of boneblack to the sugar manufacturer, and so entirely, almost, in my opinion, does the success of any and every method in which boneblack may be employed depend upon the economical and skilful use thereof, that I have devoted a section of this report exclusively to that subject. Manufactured, as it has heretofore been, chiefly in Europe, and thence imported at high cost by the planter, if boneblack be wasted, or much impaired in quality, heavy loss must inevitably ensue. If properly prepared at first, however, and subsequently revivified with skill, animal charcoal retains its properties, and may be used successfully for several crops, and an indefinite number of times.

37. Articles of a gelatinous nature, such as the extracted mucilage from the bark of the *theobruma guarcima*, the okra, and other plants, have been used to some extent in the clarification of cane

*See Appendix, note F.

juice, and as substitutes for the albumen employed for clarification by refiners and beet-sugar makers. But while the latter acts by coagulation, and collects together the mechanical impurities, the former, having no such property, is of very doubtful utility, if not injurious. And if filtration be performed in any method adopted, mixture with viscid substances is certainly productive of trouble, by obstructing the pores of the filters, while it would also impede the draining of the sirup or molasses from the sugar when granulated.

As albumen in the fluid and uncoagulated state may be dried at a low temperature, and subsequently dissolved in water without undergoing any change of properties, M. Derosne has prepared blood by drying, in France, which has been exported to and used in the colonies for clarification. Cane juice, however, contains so little foreign matter comparatively with the juice of the beet, that boneblack may be used alone for its defecation with entire success.

Besides the preceding reagents, others, such as sulphate of zinc, acetate of lead, etc., have been experimented with. But against the use of any such poisonous substances no objection can be too strong.*

The chemical theory of the defecation of cane juice is precisely similar to that for the juice of the beet; only as the former is much the purer, it is more readily defecated, and by means of a much smaller dose of lime. The greater part of the albumen in cane juice is coagulated by heat alone, while the remaining portion, like that contained in beet juice, requires lime to produce coagulation. Hence if defecation be first performed in part by heat alone, the dose of lime should be even much less in quantity than otherwise might be used. The cane, like the beet, consists chiefly of water, sugar, albumen, pectine, woody fibre, salts of lime, etc., etc. The expressed juice contains, besides the water and sugar, most of the albumen and the soluble salts; while the pectine and the insoluble salts remain in the woody fibre to constitute the begassa. An excess of lime is injurious, for the same reasons and to the same extent, in the defecation of cane or beet juice; and every precaution to prevent such excess and consequent injury is requisite alike for both.

38. The sugar manufacturer, especially in tropical countries, should exercise constant vigilance to prevent fermentation, to

* In the Sugar Planters' Manual, by Evans, London, 1847, the sulphate of alumina, decomposed by the addition of lime, is mentioned as an excellent agent of defecation.

He says: "I can conceive of no better method of defecating cane juice than this. The liquor as it comes from the filter is almost colorless, and all the after processes to which it is submitted are extremely satisfactory. I have produced sugar, from cane juice thus acted upon, equal in color to the finest clayed Havana, and possessing a sharp and sparkling grain. Unluckily, the sulphate of alumina is not an article of commerce."

There can be no chemical objection, I think, to the employment of sulphate of alumina with lime for defecation; it would be very useful to correct any excess of lime; and the only trouble apparently to be apprehended from its use, apart from the question of its cost, is the probable formation of a larger sediment or crust in the evaporating pan, unless that be avoided by filtration.

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which all saccharine juices are peculiarly liable. Every vessel should be kept as clean as possible, and the juice should never be allowed to stand for any length of time in a state favorable to fermentation. Fermentation very readily takes place in dilute juice when the temperature is between 70° and 150° Fahr. Hence to apply heat immediately to the expressed juice, first for defecation, and subsequently for concentration, is all important. And the use of reservoirs, such as are employed to collect and hold the cane juice as it flows from the mill, and in which it often stands for an hour or two, is attended with great risk, or even positive loss. By fermentation cane sugar is converted into an uncrystallizable sugar, which polarizes to the left; and this change is produced in cane juice with great rapidity, and before any escape of carbonic acid gas, froth, or other external signs, occur to give notice of the change which is going on. Nor when cane sugar has thus passed into uncrystallizable sugar, does it seem possible to restore it to its original state; while lime with fermenting juice only serves to impart a dark color to the uncrystallizable sugar, instead of acting as a remedy.

'39. In Louisiana, when the cane has been exposed to severe frost, followed by warm weather, the juice, it is said, becomes acid, and so altered that it is impossible to make sugar from it in the ordinary way. In defecation it becomes mucilaginous and ropy, and yields not a particle of crystalline sugar. Do not the changes of temperature cause the cellular tissue of the cane to be ruptured, and thus bring together the nitrogenous matter and the saccharine juice under circumstances which excite viscous or lactic fermentation? I may here add, that during the last year excellent sugar is said to have been made, by Messrs. Packwood, Benjamin, and V. Degruy, by the use of Rillieux's apparatus, from acid frosted cane juice, which by the ordinary method would, it is stated, have yielded molasses only.*

## Section III.—*On filtration.*

1. However skillfully the operation of defecation may have been performed; however faithfully the scum may have been removed by skimming; and however quietly the juice may have been allowed to stand after defecation, that the feculencies might in part collect as scum, and in part subside; the defecated liquor, though drawn off with extreme care, will still contain a portion of the impurities floating in or mechanically mixed therewith. Hence filtration is absolutely necessary, if the manufacturer would produce a perfect article. And if, by evaporation, dissolved matters become free and insoluble, as is the case with beet juice, then filtration must be repeated even several times.

As employed in the sugar industry of the world, filtration is either simple and designed solely to accomplish the object above stated, or

*See Appendix, note F.

complicated by reason of the use of boneblack, not only as a filter to remove mechanical impurities, but also as a chemical agent to separate substances chemically united with the saccharine juice, such as coloring matter, lime, etc. The filter of M. Dumont, who first introduced coarse boneblack, and to whom the beet sugar manufacture is therefore indebted for perhaps the greatest improvement which has taken place therein, is probably the best, as well as the most generally known and thoroughly tried, of boneblack filters. Simple filters are made of various kinds of cloth, and of these the "bag filter," invented by Taylor, and the "leaf filter," invented and patented by J. S. Lovering, are probably the most perfect.

2. The *bag filters* of Taylor are composed usually of a number of long and narrow cotton sacks, closed except at one end, which is left open that they may each receive a conical tube, through which the juice to be filtered enters the bag, and upon which they are tightly fastened by means of a sliding ring. The whole is arranged in a wooden box, composed of a reservoir above to hold the juice, into the bottom of which the tubes of the filters are inserted, and of a chamber below, in which the bags are suspended, and which receives the filtered juice. This chamber opens readily, that the bags may be removed and cleaned. For a further description of Taylor's filter, see plate I, figs. 1, 2, 3, 4, and the explanatory text.

The filter of Taylor, by reason of the folds of the bags, has the advantage of a very large filtering service, but the disadvantage that it soon clogs if the amount of impurities to be removed be great; in which case, the bags must be removed and washed.

The bags must be made of cotton, for woollen cloth, it has been found, is destroyed rapidly by the excess of lime in the defecated juice. This lime also often encrusts the cotton bags, as a carbonate, and impairs their filtering power. For this trouble, M. Dubrunfaut has recommended and used successfully very dilute muriatic acid, which decomposes and dissolves the crust entirely without injury to the cloth. After which, the filter must be thoroughly washed with water to remove the acid. Vinegar may be substituted for muriatic acid where it is sold or made more economically, and the cane sugar planter may manufacture it for the purpose from molasses.

3. The *leaf filter*, patented by J. S. Lovering, is composed of a series of cotton bags stretched over thin quadrangular frames, which keep the sides of the bags apart, and cause them to present a smooth even surface instead of folds, thus greatly facilitating the operation of cleaning when it has to be performed. These frames are arranged side by side in a box, and the juice, which filters from without inwards, escapes by a hole in the bottom of the frame. The juice is poured into the box outside of the frames, and the filter therefore is not clogged by impurities as readily as Taylor's filter; in consequence of which, it works more rapidly, and does

not require to be cleaned so often. Filters somewhat similar to the above have also been introduced into the refineries of England and France. They have long been used by Mr. Lovering with the most satisfactory results.

4. The *filter Dumont*. After boneblack in fine powder had been introduced into use by MM. Derosne and Payen for defecation and decolorization only, M. Dumont sought to employ it also for filtration, and to this end invented his celebrated filter; in the United States often erroneously called the Derosne filter. It consists of a wooden box, in form of a four-sided truncated pyramid, with a double bottom. The inner bottom is a metallic plate, pierced with numerous holes; upon it a cotton cloth is laid, and *coarse grained* animal charcoal, moistened with water, is then spread layer by layer; each layer being rendered of uniform thickness, and packed or pressed closely together, by means of a sort of trowel. When the boneblack has thus been formed into a compact bed or stratum of about fifteen to eighteen inches in thickness, and within five to ten inches from the top of the box, it is covered with another cotton cloth, and another metallic plate pierced with holes. The object of the second cloth and metallic cover is to collect any substances which would otherwise obstruct the interstices of the superior stratum of the boneblack—an inconvenient accident, which is easily prevented by the use of such a cover; and this cover is readily changed for another should it become itself obstructed.

It is important, to avoid false passages, that the juice should be constantly at the same level of about 3 or 4 inches above the cover of the boneblack. This is accomplished by means of a self-regulating cock. The filter will be better and fully understood by rerence to plate I, fig. 5, and the accompanying explanation.

To facilitate the action of Dumont's filter, the boneblack must be perfectly free from fine powder, which would obstruct the passage of the sirup, and thus retard its flow. To render it so, it should be sifted carefully each time after revivification. Coarse-grained boneblack may be revivified an indefinite number of times by a red heat; and if a small portion newly made be added to replace the loss in fine powder when sifted, it will last for a long time without needing any further treatment. The fine boneblack should be used in clarification.

By the beet-sugar makers it is thought best not to give to Dumont's filter a larger size than one cubic yard, because they thus become difficult to clean and recharge, and impede the operations. There is less loss of time and the filtration takes place more rapidly with a number of small filters, than with one large one.

In the West Indies, M. Derosne has introduced for the filtration of cane juice, filters of boneblack of much larger size than those of M. Dumont. They are made of boiler iron, are cylindrical in shape, and their dimensions are about eight or ten feet in height, and four or five in diameter. Such filters have also been used by refiners. They have the advantage over small filters of filtering more rapidly, in consequence of the pressure of the liquid, but

they are less readily charged and cleaned. While, therefore, these filters may be used for cane juice, or by refiners, they cannot probably be employed by beet-sugar manufacturers, in consequence of the greater amount of feculencies contained in the beet, and the considerable excess of lime in the defecated juice.

5. The *filter Peyron* is another form of metallic filter, to be used like that of Dumont, with coarse boneblack both for filtration and declorization. It is intended, however, to act continuously, and without renewal of the boneblack. This filter is cylindrical, in height two and a half metres, and in diameter one metre. The top is closed with a perfectly tight cover, and the vacant space of the double bottom communicates by a tube and cock with the top of a second and smaller filter, so that the sirup which has filtered through the first passes through the second, from which in like manner it proceeds through a third. The closed top permits the use of hydrostatic pressure to increase the rapidity of filtration, and the juice enters the first filter for that purpose by a tube from a reservoir above. The double bottom of each filter of the series is also provided with another outlet and stopcock, to permit the fluid contents to be drawn off at any time, if desired.

The filters of Peyron are charged, like those of Dumont, with coarse boneblack, carefully compressed in layers, after which the fine powder is washed out thoroughly with water; and when this flows perfectly clear, the sirup is allowed to pass into the filter, and to remove the water *by displacement*. As soon as the water which escapes from the double bottom is sweet to the taste, it is collected in the reservoir to be evaporated. After the sirup ceases to flow freely, hot water is used to displace that portion absorbed by the boneblack; and as soon as the density of the escaping liquid becomes feeble, it is no longer collected. The hot water is then allowed to flow through the filters until they are washed perfectly. Fermentation soon commences in the filter, by reason of the dilute sirup and nitrogenous impurities absorbed by the boneblack; and after twenty-four hours, when the fermentation is considered complete, and the impurities taken up by the boneblack are thereby destroyed, the filter is cleaned, to prepare it for work a second time, by first passing through it for half an hour a jet of high steam, and subsequently washing it thoroughly with hot water.

These filters were invented in 1837, and received not only the favorable consideration of the Academy of Science at Marseilles, but also the praises of two refiners, one of Berlin and the other of London, who adopted them; in consequence of which, they were subjected, in the refinery of M. Bayvet at Paris, to a fair and full trial, by a committee of the *Société d'Encouragement*, which resulted in their being condemned. What was the cause of their failure seems not to have been determined satisfactorily by the committee; but it was probably owing to the lime taken up by the boneblack, and which fermentation is insufficient to remove; for, if a weak solution of sugar ferments, it is converted first into alco-

hol and carbonic acid gas. The latter would unite with the lime to form an insoluble carbonate, while the alcohol is changed into acetic acid only by absorbing oxygen from the air, which is excluded in great measure from Peyron's filter by its tight cover.

6. By refiners the sirup is always filtered immediately after clarification. For this purpose, in the old method, it is strained through a blanket spread over and sustained by a basket—a rude contrivance, which in the improved method is replaced either by Taylor's bag filter, or the leaf filter.

By filtration through cloth, the grosser mechanical impurities are separated; but subsequent filtration through coarse boneblack is essential to remove coloring matter and any excess of lime which may have been used. For these important objects, upon which the beauty of the sugar chiefly depends, Dumont's filter, or better perhaps the large filter of M. Derosne, should be and is employed.

By refiners, boneblack is used principally as a decolorizing agent; and some of them, who add it in fine powder, do not employ a coarse-grained article; yet so long as lime continues to be used for defecation, animal charcoal seems likely also to be found indispensable for separating any excess which may remain in the sirup, and which, if there be even a slight portion of *glucose* therein, would greatly impair the color unless removed.

7. In the beet-sugar manufacture the juice is always filtered immediately after defecation. It is then usually evaporated to 15° Beaumé, which is done the more readily in proportion as the defecation has been the more complete. During this evaporation a calcareous deposite takes place; which, if it settle on the bottom of the pan, encrusts it, and often gives trouble. Most of the manufacturers, therefore, throw in a portion of fine boneblack, which not only acts mechanically to protect the pan, by gathering upon itself the calcareous sediment, but also contributes greatly to the purification of the juice. After this concentration, the juice is filtered a second time, and then again evaporated to about 27° Beaumé; during which a calcareous sediment separates, but in much smaller quantity than the first. From this sediment the sirup is rendered free by a third filtration; after which it is evaporated to granulation.

These filtrations are all usually performed in Dumont's filters, and the boneblack is used rather as an agent to correct the effects of lime, and at the same time to perform the mechanical office of filtration, than for any decolorizing properties it possesses. Indeed, decolorization is regarded as a secondary and incidental matter.

8. By the manufacturers of cane sugar, filtration, though extremely important, has been, and is at present, generally neglected. After defecation, the cane juice passes from pan to pan, with no other attention than to skim off such feculencies as rise upon the frothy surface of the boiling sirup; and when once the juice arrives

in the battery, no matter how impure, it is evaporated to the striking point. Calcareous deposites form upon the bottoms of the pans, and do great injury by interposing a non-conducting substance between the heated metal and the liquor to be evaporated; in consequence of which, the juice is evaporated slowly, and the pan becomes heated very intensely in places, which exposes the metal to rapid oxydation, and often burns the sugar.

This calcareous sediment should be removed from the juice by filtration, and fine boneblack should also be used to prevent the deposite from encrusting the evaporating pan.*

9. If carefully defecated cane juice be filtered through boneblack, and, after evaporation to 27° Beaumé, it be filtered again, the coarse boneblack employed for filtering immediately after defecation being such as had already been used, when freshly burnt or revivified, for decolorizing and filtering juice of 27° Beaumé;—we have the process copied closely after that of the beet-sugar makers, and recommended by M. Derosne as the method to be followed in the use of the improved apparatus he has constructed. The results obtained by this process in the West Indies leave nothing to be desired with reference either to the quality or the color of the sugar when the evaporation is performed by means of Dégrand's vacuum pan and condensing tubes.

With open steam pans for evaporation, fine boneblack might be used with advantage; and if the juice be permitted to flow directly into the defecator to prevent fermentation, and then to proceed uninterruptedly and promptly from operation to operation, filtering through boneblack after defecation; next evaporating with fine boneblack and by steam to 27° Beaumé, then filtering again through fresh boneblack in grains; and, lastly, evaporating by steam to the striking point, I do not doubt that, with good cane juice, excellent sugar may be thus made. The process is that of the beet-sugar manufacture of France, and it certainly involves far less outlay of capital than is required by the very expensive apparatus of Derosne. Perhaps Taylor's filters, or the leaf filter, may be advantageously substituted for the boneblack filter in the first filtration; cloth filters being the best adapted for the removal of mechanical impurities, while boneblack is requisite for decolorization, and as a remedy for excess of lime.

10. It is somewhat singular that the planters of the cane have not generally used filters, at least of a rude sort—something analogous to the blanket and basket arrangement of the old refiners; and the more so, because they are well aware of the calcareous deposite, or crust, which falls upon and adheres to the bottoms of the evaporating pans, and which sometimes gives considerable trouble.

Dutrone seems to have fully understood the importance of filtration. He says:† "After having ascertained the absolute impossi-

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* See Appendix, Note G.

†See Dutrone Précis Sur la Canne, p. 157.

bility of removing entirely, by skimming, both the feculencies which are proper to the expressed juice and the earthy matters which are foreign thereto, which are always found in it in greater or less proportion, I have seen that it was indispensable to filter and allow the sirup to repose before cooking it; and I have invented for that purpose two basins, which perform the office marvellously well, and with the greatest advantages.

"These basins, called filtering basins, (*bassins à filtrer*,) should be large enough to hold all the expressed juice, evaporated to 24 or 26 degrees Beaumé, which the mill can furnish in twenty-four hours; they should be made in masonry, lined with lead, and covered with several cases with wicker bottoms. Upon these bottoms, as filters, are spread, first a woollen cloth, then a cotton cloth and a copper sieve. Two pipes of lead establish communication with the train; one conveys the syrup into the cistern at the foot of each basin, from which a negro takes it and pours it upon the filters; the other, of which the opening in the bottom of the filtering basin is closed by a stop-cock, carries the filtered sirup back to the striking pan."

Rude as this contrivance of M. Dutrone is, compared with the bag or leaf filter of the present day, it was an improvement of great merit at that time, and might even yet be employed with advantage by planters who cannot readily obtain better apparatus. The filtering part being simply the copper gauze and the two cloths upon a wicker bottom, it is easy for any one to construct such an arrangement, or to contrive some equivalent substitute; while any vessel of sufficient capacity, and which may be readily cleaned, will supply the place of the basin of Dutrone.

In Louisiana, on the estates which have adopted N. Rillieux's vacuum pan and method of making sugar, the leaf filter of J. S. Lovering and the boneblack Dumont filter are both employed; but no other filter than the large filter of Derosne above described is used upon the plantations in Cuba, which are provided with the apparatus constructed by M. Derosne, and which I examined when there. The propriety and advantage of using cloth filters to remove gross mechanical impurities, and fine boneblack if it be added, instead of requiring the whole to be done by the granular boneblack filters, does not, in my opinion, admit of doubt.

### Section IV.—*On evaporation.*

1. Much more attention and ingenuity have been bestowed on the evaporation of saccharine solutions than upon any other process connected with either the manufacture or the refining of sugar. In most of the tropical countries where sugar is made from the cane, fuel has become scarce; hence the planter, though he in many other matters follows rude methods, yet places his pans so as to economize the heat. By the usual arrangement of pan after pan upon a horizontal flue leading from a single fire, great surface is exposed for the rapid evaporation of the juice, and at the same

time for the complete abstraction of the heat from the current of hot air which escapes from the consuming fuel. The air thus arrives in the chimney, to a great extent, deprived of excessive heat, and unnecessary waste of fuel is avoided. But though well calculated to economize fuel, the ordinary train is in one respect, especially, a most barbarous contrivance; the battery or striking teache has a hemispherical bottom, exposed directly to the most intense action of the fire: when therefore, the concentrated sirup is removed from it by dipping, the last portions, as well as the film which sticks upon the sides, are always carbonized, and the caramel thus formed greatly impairs the color and value of the sugar. By the beet-sugar makers and the refiners the injurious effects of caramelizing or burning the sirup have been not only fully appreciated, but perhaps even somewhat overrated; for they seem not to have attached sufficient importance to defecation and to accidental fermentation. Hence numerous arrangements for evaporating rapidly, and at low temperatures, have been invented to prevent injury by overheating; but in some of these arrangements proper regard has not been paid to economy in the use of fuel.

The problem of evaporation of saccharine solutions must be considered as that of obtaining from the fuel employed the maximum effect in converting the water of solution into vapor without injury to the sugar produced. But to accomplish this object in the shortest possible time, even if imperfectly, is in some places and at some times far more important than to realize an ideal perfection of products manufactured; it being more profitable to make a large quantity of rather inferior sugar than a smaller amount of prime quality. Besides to avoid night-work as much as possible is greatly to be desired by the planter for the sake of the negroes. Nor is rapidity of evaporation of less importance to the refiners, for the capital invested in refining establishments is usually very large; and to render it most productive, the business done should be as great as possible.

2. In the following observations I propose not only to describe but also to discuss the merits of the principal arrangements of evaporating apparatus which have been invented and tried upon a large scale; and in forming an opinion I am governed equally by the testimony of manufacturers with reference to their experience, and by the conformity or nonconformity of each arrangement to such general and well established laws of physics as fit it for attaining the ends of economy of fuel and rapid evaporation at low temperatures; which ends, the preceding remarks show to be the desiderata in any apparatus invented for evaporating sirup.

The laws of physics to which I have reference, and which govern the phenomena of evaporation, are simple and few in number. They should be familiarly known to every manufacturer of sugar, and therefore may appropriately find a place here, especially as reasons for the opinions and conclusions I may state, though their demonstration and illustration properly belong to treatise on natu-

ral philosophy, to which I therefore refer for more complete information.* They are as follows:

1st. It is impossible by any mere mechanical arrangement to create heat, or any other power.

2d. To convert a given amount of water into vapor, the same quantity of heat is absorbed, whatever may be the temperature, high or low, at which the evaporation takes place: for the sum of the sensible and latent heat in vapor is a constant quantity.

3d. Evaporation in vacuo takes place more readily than in atmospheric air, in consequence of the resistance of the latter to the diffusion of the vapor.

4th. When heat is communicated by contact, the amount absorbed is proportional to the number of points of contact, the temperatures being the same.

5th. When water passes at 212° Fahrenheit into steam, it absorbs 1000° of heat, which becomes insensible to the thermometer, or latent; and conversely, when steam is condensed into water, it gives out 1000° of latent heat, which thus becomes free, and affects both the thermometer and the senses. Hence, steam of 212° Fahrenheit will, in condensing, heat five and a half times its own weight of water from 32° to 212° Fahrenheit, or from the freezing to the boiling point.

It is approximatively, though not perhaps fully established, by experiments, that the same amount of heat is always produced by the combustion of any given substance, at whatever degree of heat, high or low, it may be burnt, yet the loss or waste of heat varies greatly with the circumstances and method of application. To determine this question exactly, more accurate and delicate methods than any heretofore used seem to be requisite. Yet such has been the skill of some experiments made, that we may for all practical purposes, assume it to be rigidly true that fuel produces the same quantity of heat, in whatever manner consumed.

3. The evaporation of liquids is an operation which has to be performed not only by the sugar manufacturer and refiner, but also, and in a great variety of ways, by persons engaged in the different arts.

The following classification probably includes all the methods in use:

1. Evaporation by exposure to the air;
2. Evaporation by artificial currents of air;
3. Evaporation by flame in open or close vessels;
4. Evaporation by steam in open or close vessels;
5. Evaporation in vacuo, and by steam.

Apparatus may be, however, and is contrived, in which these methods are combined, to produce a greater effect.

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*See Lardner's Cabinet Cyclopedia, volume on Heat, or Traité de Physique, either of Biot, Pouillet, or Despretz.

*Evaporation by exposure to the air.*

4. Evaporation by exposure to the air at atmospheric temperatures, though a familiar operation in domestic economy for the preservation of fruits, &c., is yet practised on a large scale only for the extraction of common salt from sea water, the usual arrangement for which is either a series of large shallow basins, into which the sea water is allowed to flow by channels, which are closed afterwards to prevent its esaape or further supply, or else a tank from which the salt water descends in divided streamlets through piles of thorns, which therefore expose a large surface of brine to the air before it escapes into the large shallow reservoir beneath.

Evaporation by air may be considered as absorption of the vapor by the air immediately in contact with the liquid, which air thus becomes saturated. Hence, it is evident that such evaporation will be proportional to the surface of the liquid exposed; that it will increase if the temperature of the liquid increases, because the vapor then has greater density; and that currents produced by winds or artificially will, by removing the saturated portions of air, and replacing them with fresh and drier portions, greatly accelerate the action.

Various combinations of evaporating apparatus have been contrived, particularly for the concentration of defecated beet juice, in which the liquid is exposed in films to the air, at a temperature near that of boiling water. Most of these arrangements act continuously, the juice to be evaporated being supplied uniformly as the concentrated sirup escapes, which economizes manual labor. They generally consist of hollow inclined planes, upon which the sirup is received at the top, and heated by steam applied between the upper and lower surfaces. To diffuse and retard the descent of the sirup, so that the action may be of sufficient duration, these inclined planes have an undulated surface. Some of them are made of copper tubes closely soldered together, and which, while they present a grooved retarding surface, also serve as pipes to convey the steam. M. Derosne has invented an apparatus of this kind, in which he causes the liquid to traverse the whole surface of the inclined plane, by means of numerous strips of metal placed across, and which are not quite as long as the inclined plane is broad. The space between these strips forms a continuous channel through which the juice flows alternately in opposite directions, and thus passes slowly over the whole surface before it arrives at the bottom.

Among the systems for evaporation by exposing thin films of heated juice in the air, that invented by MM. Martin and Champonnois is probably the simplest. It is composed of a number of columns, about forty inches in diameter, and seventeen feet in height, made of thin sheet copper. Each of these columns is provided with a circular receiver at top, which distributes the juice, as it flows from a reservoir, in a thin sheet over the column. As it descends, the juice is evaporated by exposure to the air and

by the heat furnished by the steam within the column, which is supplied by a pipe from a steam boiler. Three successive operations, and from seven to nine minutes, suffice to concentrate ordinary beet juice to 30°. Besides, the apparatus may be readily cleaned.

In the system of M. Dégrand, which has been employed by M. Derosne for making cane sugar, evaporation is performed by the double influence of air externally, and heat from steam within, applied to a thin film of juice upon a serpentine pipe of sheet copper; the steam being that generated by the final evaporation of the concentrated juice in a vacuum pan. (See plate IV, figs. 1 & 2, and description; also, in the sequel of this section, the article on evaporation in vacuo.)

5. It seems to be a disputed point whether or not saccharine solutions and juices are injured in evaporation by exposure to the air. M. Payen, whose opinion and experience are entitled to great credit, remarks, that it is the more important to refute the belief that sirups are injured and rendered dark colored in evaporation by an elevated temperature, or by the action of the air aided by heat, because these views have been sustained by eminent scientific men, and given rise to most ruinous speculations. In corroboration of his opinion that injury is done rather by long duration of the heat, M. Payen adduces the facts, that boiling for thirty or forty-five minutes, according to the old system, deepens the color, and renders a much larger quantity of sugar uncrystallizable than rapid concentration in six or eight minutes by means of a *tilt* or *bascule pan;* that slow evaporation, by steam, of large quantities of beet juice at a temperature below that of boiling water, far from producing a better result, gives very dark and perfectly uncrystallizable sirups; that slow evaporation, either by an open fire or by a water bath, gives equally bad results. As for exposure to the action of the air during concentration, M. Payen remarks that, far from considering it very prejudicial, the effect should be regarded as almost nothing; for comparative experiments made in vacuo, in carbonic acid gas, in nitrogen, and in atmospheric air, gave him like results for like temperatures and times of evaporation.

Again, it is considered as a fact fully established by the use of apparatus similar to that described above in the manufacture of beet sugar, that saccharine juices do not sustain appreciable injury in concentration by exposure to the air; and for this we have the authority of the most intelligent and experienced manufacturers and chemists. On the other hand, Hochstetter, who made many interesting experiments on sugars, affirms, "that saccharine juices are rapidly changed by the action of the air," and expresses the opinion "that those systems of evaporation where beet juice drips over warm surfaces, (plates,) and by great contact with the air loses its water, which evaporates, ought to be rejected altogether."*

*See Franklin Institute Journal, March, 1844, page 179, translated from the Journal für Praktische Chemie, May, 1843.

Still the results of experience in large manufacturing operations, conducted by men of such skill and ability as MM. Payen, Derosne, and others, are certainly more entitled to confidence than any experiments on a small scale.

6. With reference to economy of fuel, apparatus for evaporation by large heated surfaces exposed to the air is certainly very objectionable; for not only is the heat generated employed for the conversion of the water of the juice into steam, but also the air itself in contact with the apparatus becoming heated, ascends and gives place to colder air, which, in turn, also passes away in the same manner—thus producing a constant current, by which great waste of fuel must occur. From this objection the system of MM. Dégrand and Derosne is, however, free; for in it the serpentine tube, upon which the juice is evaporated to 27° Beaumé, is employed as a refrigerator or condenser of the vapor within, to aid in forming the vacuum in the pan.

The steam employed for supplying by its condensation the latent heat requisite to convert the water of the juice into vapor can only evaporate a quantity equal to its own weight, or to the amount of water from which that steam was generated; and as considerable loss of heat must occur by currents of air in the use of the above described apparatus, it follows that evaporation in vessels by steam, applied by pipes, hollow bottoms, &c., must be attended with much greater advantages if fuel be scarce or costly, than the employment of systems by which large surfaces are exposed. And if evaporation in the latter be very rapid, still, equal rapidity can be readily commanded in other steam apparatus by extending the heating surface, which is easily done, either by increasing the number of the pans or of the steam pipes.

*Evaporation by artificial currents of air.*

7. Mr. G. W. Kneller patented an invention which was used for some time in a refinery in London, which consisted of a number of pipes pierced with numerous orifices, and immersed in the evaporating pan, through which orifices cold air is forced, by means of a bellows or other blowing machine, into the saccharine solution. The air cools the liquor, which would otherwise be heated to a high temperature by the direct action of the fire, and at the same time conveys off the vapor which it absorbs.

8. In France, M. Hallette invented a concentrating apparatus, which consists of two concentric cylinders placed in an inclined position, which revolve about their common axis, and are heated by steam from a separate boiler. The space between the two cylinders is closed at the two ends, and constitutes the steam chamber, by which the heat is applied to the juice which flows in at the top upon the surface of the inner cylinder, and escapes below in a concentrated state. The vapor generated by the juice, and the heated air within, cause a strong current of air to pass through the

revolving cylinder, the revolution of which evidently serves to expose constantly a thin film of juice upon the inner surface. This apparatus is said to have worked well in an Austrian factory, as well as in France, for a number of years. The juice is evaporated very rapidly by it, but there is of course considerable loss of heat, and consequent waste of fuel, by the current of cold air which is continually passing in at one end and escaping at the other in a heated state. This current of cold air must also condense a considerable portion of vapor already liberated, and restore it to the liquid state.

9. An apparatus for the evaporation of saccharine juices by the combined action of hot air and of steam has been invented by M. Brame Chevalier, and used both by himself and others for a sufficient length of time to test the principles thoroughly upon which it depends. It is composed of a blowing apparatus, moved by a steam engine; of a vessel filled with tubes for heating the air; and of an evaporating pan furnished with a double bottom, into which the air is forced, and from which it escapes by a large number of small orifices through the inner bottom. In this evaporating pan a set of steam pipes is also immersed with steam from the boiler of the engine, which contribute greatly to the effect of the heated air. The water formed by the steam condensed in these pipes is conveyed back to the steam boiler.

The vessel for heating the air consists of a cylinder placed vertically, and a large number of copper tubes or steam pipes, which receive steam from the boiler and heat the air which is forced lengthwise through vacant spaces between the pipes.

In this apparatus, five or six minutes are sufficient for the evaporation of the sirup, (such as is used in refining,) and the temperature does not exceed 175° Fahrenheit, though the steam pipes should be heated even to 300° Fahrenheit—a fact which is attributed to the large amount of latent heat which is absorbed by the rapidily evaporating liquor. But the apparatus is very complicated and costly, and wastes a large amount of fuel for the purpose of heating air. As it requires a steam engine and other expensive machinery, it must be admitted that a vacuum pan, which requires a similar outlay of capital, but is both established by experience and more economical, is certainly to be preferred.

It is worthy of mention that, by the use of the apparatus of Brame Chevalier, the action of the air on sirups during the evaporation has been fully tested, and found to produce no perceptible injury either in quality or in color.

*Evaporation by flame in open or close vessels.*

10. The direct application of flame to vessels containing solutions to be evaporated, although used often in other branches of the arts with perfect results, as, for instance, in generating steam for engines, is yet attended with the most decided injury when employed for saccharine juices or sirups. So great and so una-

voidable is this injury, that it no longer admits of doubt or question that all such arrangements should be abandoned.

In the pans at present generally used, the sugar contained in the sirup which sticks to the sides, as well as that which remains in the bottom, is invariably burnt or caramelized by the fire whenever the contents of the pan are removed by dipping; so that Dr. Ure not inaptly styles them "*sugar frying pans.*"

11. The *bascule* or *tilt* pan, (see plate I, figs. 8 and 9,) though designed, by more rapid evaporation and by pouring the whole mass of concentrated sirup at once into the cooler, to correct the evils of the common system, is still but an imperfect remedy, and may be regarded as an intermediate step between old faulty arrangements and the new highly improved steam apparatus. It consists of a large shallow copper pan with a spout or lip, and turns on an axis by means of a chain and pulley, so as to empty its contents into a large copper vessel or cooler, and receives its charge from a reservoir of juice or sirup above, provided with a stop-cock to govern its action.

Although the bascule pan evaporates and pours with great rapidity, and thus prevents the sirup being long exposed to an intense heat when concentrated, it is still attended with great waste of fuel in consequence of the air and gas from the fire passing into the chimney at a high temperature. It cannot, therefore, be substituted for the common train of pans in places where economy of fuel is desirable; but, even if the bascule pan were free from this objection, evaporation by steam would be infinitely preferable, by reason of the perfect control it gives in the application of heat.

12. Evaporation in close vessels—that is to say, in such as permit the escape of the vapor by openings just large enough to prevent any considerable increase of elastic force above that of the atmosphere—is more advantageous than in open vessels; for in the latter, until brisk ebullition removes the stratum of air incumbent upon the syrup by the formation of a sufficient volume of steam, a circulation of cold air from the sides is established, which conveys away much of the heat, and produces a proportionate loss or waste of fuel.

*Evaporation by steam in open or close vessels.*

13. All the numerous and various arrangements which have been invented, and more or less employed, for the evaporation of liquids by steam, consist essentially of a boiler, for the generation of the steam, similar to and constructed like those used for steam engines, and of one or more evaporating pans, provided either with a double bottom or a steam pipe, and sometimes with both, for the application of the steam.

The evaporation of syrup by steam is attended with great advantages: first, because they cannot so readily be injured by overheating; secondly, because the operation can at will, and instanta-

neously, be either commenced, arrested, or continued at a constant and suitable temperature; and, lastly, because a single steam-boiler serves to supply any number of evaporating pans, and, therefore, the loss of heat which occurs by multiplying the number of furnaces is avoided, as a single furnace answers for the whole.

Although, if the furnaces be so constructed as to render the heat developed by the combustion of a given amount of fuel equally available in each case, evaporation by steam will be as economical as by the direct action of the fire, it cannot, however, be attended with actual gain; for it may be considered self-evident that the steam generated by the consumption of any given amount of fuel cannot give out in condensation more heat than is required for the vaporization of a quantity of water equal to that from which the steam was formed.*

14. It is of great consequence that the pans should present a sufficient extent of evaporating surface; for upon that chiefly will depend the rapidity with which they will operate. It matters not whether this surface be presented by a double bottom, or by pipes, provided the metal be endowed with equal power of transmitting heat, for it has been ascertained that form has no effect upon the generation of steam, though upon it depends, to a great extent, the strength of the apparatus, especially in resisting the elastic force of the steam. That the evaporating power of any apparatus depends upon the surface exposed, is evident from the consideration of the phenomena which occur. The heat, whether communicated by radiation, and contact with flame and hot air, or by the application of steam, is received first by the exterior surface; from this surface it is conducted from particle to particle of the metal, until it arrives at the inner surface, where it is absorbed by the particles of the liquid immediately next to the metal, causing these particles either to expand and rise to a higher level, at the same time giving place to others, or else converting them into steam. The quantity of heat absorbed, and the number of liquid particles acted upon, will, of course, be proportional to the extent of heating surface; and if the exterior surface be, as it is in all pans, heated by steam kept at a constant temperature, then the quantity of heat transmitted from the exterior to the interior surface will be directly as the conductibility, and inversely as the thickness, of the metal forming the pan.

As the conducting power of the metal, of which the evaporating pan is composed is a matter of some importance, it is a fact which should be borne in mind, that copper conducts heat more rapidly than iron; and these are the only metals which can be used for the evaporation of saccharine solutions. Copper possesses also the advantage of being less readily oxydized; and though its first cost is

* This proposition may be put in another, and to some, perhaps, a more evident form: the steam from the boiler is a mere heat-carrier, to convey what it receives to the juice, give it up, and return. It may lose part by the way, but can create nothing.

much greater than that of iron, when worn out it sells for nearly as much as the original value of the materials. For resisting the force of high steam, and for sustaining pressure, the superior strength of iron entitles it to preference: besides these, there are other comparative advantages and disadvantages in working, familiar to those who manufacture such apparatus, and which materially affect the cost; but such is at present the skill of these manufacturers, that it may perhaps be confidently asserted that any thing can be made of iron which it is possible to make of copper, and conversely.

15. To combine great resistance to the elastic force of steam with facility in transmitting heat, steam pipes of small diameter (say one or two inches) are preferable to large double bottoms; for the strength of hollow bodies, when subjected to the action of disruptive forces, is inversely proportional to their diameters: pipes may, therefore, be made thinner than double bottoms; and we may thus attain rapidity of evaporation without loss of strength to the apparatus. But, in reducing the thickness of the metal, we must not diminish the heating surface; for the amount of heat gathered either from flame or steam depends upon that surface, as we have already seen; and if we at the same time decrease both the thickness and the surface of the pan, we counteract by one change the advantage which we derive from the other.

16. In using steam for the evaporation of liquids, it is of the utmost importance that atmospheric air should be entirely and readily expelled from the apparatus at the commencement of the operation; for air is not only a bad conductor of heat, but it also opposes considerable resistance to the circulation of vapor through it; and it therefore serves both to diminish the heating surface, which is limited to that in contact with steam, and also to retard the replacement of condensed steam by fresh portions thereof. When, however, the apparatus is filled with steam only, this steam condenses and forms a vacuum with the metal, which vacuum is instantly filled again with steam, to be in turn condensed. Thus successive portions of steam give off their heat, and a rapid circulation takes place.

17. In every arrangement intended for evaporation by steam, it is important that the water formed by the condensation of the steam should readily escape, so that it may not obstruct the apparatus; and if this water be conveyed back to the boiler, it will not only serve to replenish it, but also, by reason of the heat retained, be productive of economy of fuel.

18. In the use of high steam for evaporation, constant care and vigilance are necessary, for the operation goes on much more rapidly at first, and the consumption of steam decreases as the liquid becomes more and more concentrated. The pressure of the steam must therefore be constantly watched, and the fire regulated

accordingly. This should be done by a mercurial gauge, and not by the safety-valve alone. If a number of evaporating pans be worked at the same time, the superintendent may follow a systematic order of operations, which will keep the amount of work nearly constant, and in a great measure avoid irregularities in the pressure of the steam; a self-regulating damper is highly desirable.

19. Of the numerous arrangements of open evaporating pans furnished with steam pipes, that of Taylor was the first, and it has perhaps had more influence upon the beet-sugar industry of France, and been more fully tested, than any other. Although more perfect arrangements have, to a great extent, superseded it, still it is particularly worthy of notice, since it may be considered the next step, after the bascule pan, in the progress of the manufacture of beet sugar. For a more full description of it, see plate II, figures 1, 2, and 3, and the explanation. It consists essentially of a pan and a series of double concentric tubes, so connected together that they form a sort of grate, movable upon an axis at one end, that they may be elevated to permit the pan to be cleaned. The axis upon which the system of tubes turns is divided lengthwise, by a diaphragm, into two chambers. The steam which is conveyed into one of these chambers passes thence through the inner tubes, and returns by the channel between the outer and inner tubes into the other chamber of the axis. From this chamber the condensed water is drawn off, to be carried back into the boiler. When the sirup is sufficiently evaporated, the pan is emptied through the bottom, by a cock for the purpose. The objections to Taylor's pan are, its complicated structure, and the consequent liability to derangement and difficulties of workmanship. The inner tubes present no evaporating surface, while they add considerably to the weight of metal, and therefore to the first cost.

20. A much more simple arrangement has been contrived by M. Dubrunfaut, and which is said to be successfully used in France, (see plate II, figs. 4 and 5.) It consists of a simple continuous tube, passing backwards and forwards a number of times; the two ends of which serve not only for the entrance and escape of the steam, but also as pivots upon which the bent tube turns when the pan is cleaned. If this tube be constructed of metal sufficiently thin to transmit heat with great rapidity, it would perhaps be wanting in strength. A more serious objection to this apparatus lies in the difficulty of constructing bent tubes of copper, which are very apt to leak, even if tight at first, after they have been subjected for a short time to the changes of temperature which occur in use, and especially when the curves are small.

21. Other pans have been used which are provided with a serpentine tube, somewhat similar to the ordinary worm of the distiller; the spires of which, however, are situated nearly in the same plane. Of these, that of Hallette (for a more particular description of which, see plate II, figs. 6 and 7) is probably one of

the best. The tube forms two concentric parallel spirals, and the steam passes inwards through one of these spirals until it arrives at the common centre, whence it again flows outwards by the other spiral.

22. Besides the arrangements above described, that invented and constructed by M. Pecqueur is worthy of mention. The tubes proceed from a common steam pipe; and having traversed the extent of the pan, they end in a common escape pipe. The pan itself, as well as the set of tubes independently of the pan, turns upon the axis formed by the steam and escape pipes.

In appearance this pan somewhat resembles Taylor's pan, but it differs entirely, in that the pan may be considered a bascule pan, and that the tubes are not double; the axis also is formed of two short pipes. M. Pecqueur has constructed two or three hundred pans of this description, and they have been employed satisfactorily in France. The chief advantage of M. Pecqueur's apparatus is that the short length of the tubes allows the steam to retain much of its elastic force, and to return through them without being condensed into the boiler. The steam is thus used at a higher temperature, and the juice is evaporated more rapidly.

23. An apparatus exactly similar to that of M. Pecqueur has been patented in this country by Mr. Harris; in Cuba I saw one which had been put up on the Saratoga estate, but which had failed to give satisfaction. It was made, I was informed, at one of the most justly celebrated machine factories of this country, and any faults it may be subject to are therefore to be attributed rather to erroneous mechanical contrivance than unskilful workmanship. When on that estate, I requested and obtained the permission of the intelligent administrator to try some experiments with this apparatus; and when the steam was admitted at the pressure of two and a half atmospheres, I found that the joints by which the tubes were connected to the axis were very open, permitting the steam to escape freely into the sirup. The manner in which these joints were made had apparently been the cause of the failure of the apparatus. Notwithstanding this escape of steam into the sirup, so great was the evaporating power of the tubes that the juice was concentrated more rapidly than in the common pans, and yielded a superior sugar. Had the joints been tight, I do not doubt, from the results obtained, that the rapidity of evaporation by this apparatus would have been four times as great as that of the Jamaica trains used on that estate.

Many other arrangements have been tried, but they are all simple modifications of those described; the serpentine tube and the system of Taylor are types from which they are copied, with such variations only as convenience of workmanship and use may have suggested.

I am not aware that the evaporation of saccharine solutions in close vessels and by high steam has been tried, or thought desirable, by any one. It would doubtless be attended with economy of fuel

to a slight extent by preventing a circulation of air in contact with the liquor, and the consequent abstraction of heat.

24. In the refineries and beet-sugar establishments of France the evaporating pans are furnished with wooden covers, in which there are openings communicating with flues or chimneys, also of wood, and which serve to carry off the immense volume of vapor produced. (See plate II, fig. 5.) This vapor, if allowed to diffuse itself in the building, would constitute a cloud sufficiently dense to render it impracticable to see things distinctly even at short distances.

*Evaporation in vacuo and by steam.*

25. When evaporation takes place in vacuo, it is almost instantaneous. The density and consequent quantity of water composing a given volume of the vapor formed depend only upon the temperature; the total amount of vapor given off is equal to that required to fill the space occupied by the vacuum; and the latent heat absorbed is sufficient to heat a quantity of water equal to that contained in the vapor through 1000 degrees Fahrenheit, or five and a half times the same quantity from the freezing to the boiling point. If, by means of an exhausting pump or by condensation, the vapor is then entirely removed, and the vacuum re-established, an equal quantity will be again formed; this in turn may be removed, that another portion may take its place, and so on indefinitely; the requisites to the continuity of the operation being a constant supply of water to be evaporated, and of heat to replace that which becomes latent and is absorbed by the vapor, combined with the prompt removal of the vapor by an air pump, or by condensation in a separate vessel.

From the above it is evident that, by reason of the great amount of latent heat absorbed, evaporation by steam and in vacuo will take place at a low temperature, as well as with great rapidity. The rapidity of the operation will depend, however, upon the perfection of the vacuum. It is impracticable to form a perfect vacuum; and a partial one retards the operation. If it contain vapor this will occupy the place, and prevent the formation of an equal quantity. And if air be present, the escape of the vapor will be obstructed by it; as, in illustration, water flows swiftly through an open tube, but finds its way very slowly in one filled with sand or other porous substances. Practically, the vacuum pan has been found to evaporate with great comparative rapidity, and at very low temperatures, even though the realization of a perfect vacuum be a mechanical impossibility. Indeed, the skill of the machinists of the present day is such that some of the vacuum pans made by them leave little or nothing to be desired, so that for all practical purposes they may be considered perfect.

Four different systems for evaporating in vacuo have been invented and successfully established: one by Howard; another by Roth; a third by Dégrand, modified by Dérosne; and lastly that of

Rillieux. The vacuum pan of Howard has not only the merit of priority of invention, but also of being one of the simplest and most perfect, as well as the type from which the others are all more or less copied.

26. *Howard's vacuum pan.*—This apparatus, as constructed by William Oaks & Son, of London, consists of a close vessel, nearly spherical in form, and with a double bottom, between the plates of which the steam is received, which heats the sirup to be evaporated. A pipe draws off from this double bottom the water of condensation, while a larger pipe, closed with a movable stopper, and passing through both plates of the double bottom, permits the sirup to be removed from the interior when it has been sufficiently concentrated. At the top of the spherical pan two pipes enter; one of which supplies the sirup to be evaporated, and the other leads to the air-pump which is employed to form the vacuum. A thermometer and a barometer are attached to the pan, by which the temperature and pressure are indicated, so that the workmen may know exactly the condition of the contents of the pan. And for inspecting the sirup itself directly, a complicated "proof-stick" or brass rod, having a cavity in its side, passes into the interior of the pan; this rod may be drawn out with a portion of the sirup in the cavity without admitting the air. Attached to the pipe leading to the air-pump there is a reservoir, intended to receive and hold any portion of sirup which may accidentally pass over; and sometimes the vapor passes first into a condenser, where it is in part condensed by the injection of cold water, and afterwards into the air-pump; an arrangement similar to that used in Watt's lower-pressure or condensing steam engine.

Howard's vacuum pan has been variously modified and improved; but the description given above will probably serve to convey an idea of all important features. It has also been constructed of a different form. Mr. Morgan, of Louisiana, who was the first to introduce the vacuum pan into that State for the evaporation of cane juice, and whose long experience entitles his opinion to great regard, now uses and prefers vacuum pans of a cylindrical form. The principal objection to the use of the apparatus of Howard, and which has prevented its more general adoption, has been its cost. The results it has yielded may be considered perfect with respect to the quality of the sugar; but as the air-pump is worked by a steam engine, a larger outlay or investment of capital is required than many have been able to afford. Since many planters are, however, obliged to employ steam engines for grinding the cane, I must confess that I am somewhat surprised that the vacuum pan has not been more generally used by them. Where water-power can be commanded for working the air-pump, Howard's pan may be employed with great advantage and economy; nor would it then be found very costly, as it is perhaps the simplest arrangement yet contrived.

Whenever a steam engine is used to create the vacuum, there is probably no greater economy of fuel in the employment of

Howard's pan than in the common trains, with open kettles; for, since the effect is in both cases the same, to wit, the evaporation of a given quantity of water from the juice, we may fairly conclude that to produce that effect a given amount of fuel must be consumed. Nor will it matter whether the power developed by the combustion of this fuel be applied directly, as in the common trains of pans, or indirectly by means of a steam engine, an air-pump, and a vacuum, since we cannot create power by mechanical arrangements, though we vary them never so intricately and indefinitely.

27. *Roth's vacuum pan.*—To obviate the necessity and heavy cost of the steam engine employed to form the vacuum in Howard's pan, a different apparatus was invented in France by M. Roth, which has been used extensively both by the manufacturers of beet sugar and by the refiners of that country. The vacuum is formed by condensation only, in a large and separate condenser. (See plate III, figures 1, 2, and 3.) In other respects this apparatus is very similar to that of Howard, above described. To give greater heating surface, M. Roth introduced a serpentine tube into the evaporating pan, by which improvement the syrup is concentrated very rapidly. The vacuum formed by Roth's apparatus is less perfect than that produced by Howard's, and it requires a large quantity of water—five gallons for every gallon of juice evaporated; it can, therefore, be used only where there is a large supply of water, as well as of fuel. There is evidently no more economy of fuel in the use of this apparatus than of open pans, heated by steam, or directly by the flame, and in the ordinary trains. The principal advantages are, that the temperature of the sirup does not exceed 175° Fahrenheit, and the small cost comparatively to that of Howard's pan. The system of Roth has not, to my knowledge, been used in this country or in the West Indies.

28. *System of MM. Derosne and Degrand.*—The apparatus of M. Dégrand has of late years been used in France in the manufacture of beet sugar, and much preferred to that of Roth, for the reasons that it requires less water to form the vacuum; that it is attended with greater economy of fuel, and that the vacuum need only be formed once, and at the commencement of the work. The system of Dégrand differs from that of Roth in three important features: first, in the form of the condenser; secondly, in the use of the beet juice instead of water for condensation; lastly, in discharging the concentrated sirup into a close vessel attached to the evoporating pan, and in which a vacuum has been formed, so as to prevent the entrance of air at every strike.

The condenser is composed of a serpentine tube, the folds of which lie all horizontally in one vertical plane, and the condensation is effected not by injection of water within, but by application of beet juice on the outside of this tube. The juice for this purpose is permitted to fall in fine streams upon the first fold, from which it descends similarly to the successive folds. A thin film of

juice is thus exposed upon the tube, which, in condensing the steam within, absorbs its latent heat, and passes off in part as vapor with the current of air which is established by the assent of those portions thereof which come in contact with the serpentine tube and are expanded by its heat. It is to this mutual employment of the latent heat contained in the vapor of the more concentrated sirup, for the evaporation of a portion of the water in the fresh beet juice, and conversely of the latter for the formation of a vacuum by the condensation of the former, that the superiority of the system of Dégrand must be ascribed. In all the preceding arrangements, this latent heat of the vapor from the sirup has been permitted to pass off entirely, thereby causing great loss of heat and expenditure of fuel.

M. Derosne, whose name is connected with so many valuable improvements in the manufacture of sugar, has considerably modified the apparatus of Dégrand. Plate IV, figures 1 and 2, will furnish an idea of this improved apparatus. It represents the arrangement such as I have seen it in operation in the island of Cuba, on the estate of Don Villa Urutia, and on the Amistad estate near Guines; and which arrangement is, I believe, the present most approved form. M. Derosne produces the vacuum by means of an air pump, aided by a condenser formed of two of Dégrand's serpentine tubes, using the saccharine juice for condensation; in consequence of which condenser, the vacuum is maintained readily by a far less powerful and expensive steam engine than that required for Howard's pan. He has also attempted to heat the vacuum pan by means of the vapor from sirup evaporated under pressure and by high steam in a separate and close vessel. Both of the evaporating pans were heated by internal tubes only, and were therefore without hollow bottoms. In the first, the juice, as it came from the serpentine condenser was concentrated to 27° Beaumé; and in the second, or the vacuum pan, it was then evaporated to granulation. The heat contained in high steam was therefore used three times successively, before it was allowed to pass off: first, for concentrating juice to 27°; secondly, for evaporation in vacuo; and, thirdly, in the tubes of Dégrand for evaporating the film of juice on their exterior surfaces; after which it escapes. That, from this triple use of the heat contained in the steam, great economy of fuel should ensue, follows as a necessary consequence, but I have no knowledge of the result of the experiment.

29. From the preceding description and discussion of this apparatus, it is evident that the only advantage of the system of Dégrand over the vacuum pan of Howard is greater economy of fuel, resulting from the successive use of the latent heat contained in the steam. Both give perfect results with respect to the quality of the sugar. A specimen of sugar made with Dégrand's apparatus on the Amistad estate, and taken by myself at random from a large quantity, has yielded me 100 per cent. as the result of chemical analysis, being therefore apparently pure. Its solidity, crystalline grain, and beautiful transparent whiteness, are also equal to those

of refined loaf sugar, for which it would be mistaken. To produce this result, however, the use of boneblack filters is indispensable. From cane juice similarly defecated and decolorized, equally perfect results are obtained with Howard's pan, which has been employed so long and so extensively by the refiners, that its use and construction have been thoroughly studied and perfected by practical experience.

The disadvantage of the system of Derosne is its very complicated structure, rendering it extremely difficult of manufacture, and liable to frequent derangement. None but workmen of the highest order of skill could either make or properly repair such an apparatus. In consequence of this complexity, Derosne's apparatus must also be very expensive, both in its original cost and in its repairs. In estimating, therefore, the respective merits of Howard's pan and Derosne's train, the interest on the capital invested, the expense of repairs, and the fuel and labor required by each, are the items which constitute the data of the comparative calculation; and if, after summing up these items, it does not appear that the greater economy of fuel in Derosne's system exceeds the difference of expense in interest, labor, and repairs, then we must conclude that the new system of Derosne presents no advantages over the old and fully tested vacuum pan of Howard. I regret that I have not the data requisite to make this calculation. Perhaps such data cannot at present be obtained; for though the cost of Derosne's apparatus is known, the economy of fuel and expense of repairs probably are not. The latter would, of course, vary with the workmanship. The trains which I examined in Cuba were made in France by M. Derosne himself; their workmanship was apparently excellent. The results which had attended their use it was impossible to arrive at; for while on the estate of Don Villa Urutia bankruptcy had been the consequence of the experiments of the enterprising owner, the Messrs. Diago, on the contrary, were said to be realizing immense profits, not, however, from the manufacture of sugar from cane juice alone, but also by buying up the inferior sugars of their neighbors, and refining them into articles of the first quality. It is a false rule, however, to judge of the merits of an invention by the success or failure of particular persons who may have used it; for the economical result depends not less upon the intelligence and business habits of the individual, than upon the machine itself.

In France, and in the islands of Guadaloupe and Martinique, M. Derosne has also introduced his apparatus; but with what results, I have no accurate means of knowledge. In the island of Martinique, MM. Lébaudy and Derosne are said to have obtained the monopoly of the manufacture of sugar by Derosne's improved method, and to have established large central refineries.*

In Lousiana, during the past year, a Derosne train has been put up on the plantation of Mr. Lapice, by the skilful machinists of the

* Fabrication Actuelle du Sucre au Colonies, p. 81: Paris 1843.

Novelty Works, in New York. Its estimated cost I understand to be not less than that of those in Cuba. From the results which may attend this enterprise the planters of the State of Louisiana may fairly judge of the system; for such is the character of the workmanship executed by those machinists, that the merits of the apparatus will certainly be fairly tested.

If an abundance of fuel can be readily commanded, I do not hesitate to express the opinion that Howard's vacuum pan, combined with an open pan, heated by steam for concentrating the juice to 27° Beaumé, is decidedly to be preferred to the apparatus of Derosne, even at equal cost, though the price of the latter would probably be far greater; for while the vacuum pan of Howard has been fully tested, and perfected by experience in its construction and arrangements, so that we may safely rely upon certainty of results, the system of Derosne is comparatively new and untried. Should accidents occur, the pan of Howard may be repaired by workmen of ordinary skill; but the complicated and delicate structure of Derosne's apparatus renders it, perhaps, a task of no easy character to repair it when necessary; and if, by accident, the work is at any time arrested during the grinding season, heavy loss may ensue.

In forming an opinion of the Derosne train, the quality of the sugar manufactured by it is not the only criterion by which to judge of its merits; for this is to be ascribed to the system of defecation, and to the use of boneblack filters, according to the method employed in the beet sugar industry of France, and which is adopted by M. Derosne for cane juice, rather than to the construction of his vacuum pan. And it should be borne in mind, that if the juice be first properly defecated, and then decolorized with boneblack, sugar of equal quality is obtained both with Howard's and Rillieux's vacuum pans.

30. *The system of Rillieux.*—The use of the latent heat of the vapor from one portion of sirup, for the evaporation of another portion, has been accomplished far more perfectly and fully by an apparatus invented by N. Rillieux, of New Orleans, than by the system of M. Derosne. This apparatus has also the merit of being simpler, and therefore more easily constructed or repaired, so that it is less expensive, and less liable to derangement. It may now be considered as fully tested, and as perfectly successful; so that it may be adopted with entire security and certainty of results.

The distinctive feature of N. Rillieux's system may be said to be the *successive use* of latent heat for the evaporation of sirups, by a series of similar boilers or close evaporating pans—each being heated by the vapor from the preceding one, and in turn furnishing heat to the succeeding pan. The first of the series is heated by exhaust steam from the steam engine used for grinding the cane, and from the pumping engine, and the last is used as a vacuum pan for concentration. The vacuum is produced by means of an air-pump worked by a small steam engine. Any one of the series of pans, at pleasure, may also be connected directly with the

steam pipes, by means of cocks and tubes suitably arranged; so that it may at any moment be heated by high steam if desired. The pans are cylindrical, and are heated by numerous internal tubes; they therefore resemble somewhat the boiler of the locomotive engine as at present usually constructed. The series consists of either three or four pans; but the number might be extended, if the increase would give sufficient additional advantage to render it expedient. (Plates V, VI, and VII, and the descriptive text, will give an idea of this system.)

This apparatus is constructed by Messrs. Merrick and Towne, of Philadelphia, machinists of established reputation for intelligence and superior skill, and who have become the assignees of Rillieux's patent. To the excellence of the workmanship of these gentlemen, no less than to the merits of the system itself, is to be attributed its entire success.

The beauty and superior grain of the sugar manufactured by those who have adopted Rillieux's train does not depend, however, upon the merits of that train alone. The juice, after defecation with lime in defecators similar to those employed by the beet-sugar makers of France, and described in section 2, is filtered first through cloth, and then through boneblack; after which it passes successively into the first, second, and third boilers. In the third boiler it is concentrated to 27° Beaumé; and it is then again filtered before it enters the fourth or last pan, to be evaporated in vacuo. The filters employed are the leaf filter of Lovering, and the filter Dumont. If a train of three boilers be used, then the juice is concentrated to 27° in the second, and evaporated in vacuo in the third. From the above, it is evident that Rillieux adopts the method employed in France for clarifying beet juice, and which has been applied successfully to the juice of the cane in the West Indies, as above mentioned. And if cane juice be thus treated, a perfect article will, as already stated, be manufactured from it by evaporation in vacuo, whatever may be the vacuum pan employed. While, therefore, we must ascribe to N. Rillieux's system of boilers the advantage of superior economy in the use of fuel, and to the apparatus, as executed by Messrs. Merrick and Towne, the merit of simplicity, and consequent perfection of mechanical arrangement, as well as of excellent workmanship, we yet must consider other systems as equally capable of producing sugars of perfect quality in grain and color, provided they be properly combined with filtration and the use of boneblack.

To planters who are obliged to depend greatly upon the begassa of the crop for their supply of fuel, Rillieux's system presents great advantages over all others; for the economy of fuel is so great in it that the begassa alone is amply sufficient for the crop, even in Louisiana where the immature nature of the cane and the humidity of the climate are far less favorable for drying begassa, and where, therefore, this article is much inferior to that used in the West Indies. But if fuel be abundant, an open steam evaporating pan for concentration to 27° Beaumé, and a simple vacuum pan, either that of Howard or that of Rillieux, will give equally

satisfactory results; the juice being in each case similarly defecated and filtered through boneblack.

When in Louisiana I visited the plantation of Messrs. Benjamin and Packwood, at their invitation, and carefully examined the apparatus of Rillieux, constructed for them by Messrs. Merrick and Towne. From what I learn from those intelligent gentlemen, as well as from what I then saw, I can bear witness to the entire success of the system.

31. The following communication of Mr. T. J. Packwood, extracted from the New Orleans Bee, will be of interest to many:

"Myrtle Grove, 1844.

"Dear Sir: Your favor of the 12th instant has been received, and with pleasure I reply to your inquiries respecting Mr. Rillieux's apparatus.

"Mr. R. contracted to furnish me with an apparatus for the fabrication of sugar entirely by steam; that the quantity of molasses should be reduced to the half of that produced by the old process; that the sugar made from it should be equal to that produced by a vacuum pan, without any refining process; that it should be capable of producing an average of 12,000 lbs. of sugar within 24 hours; and that the fuel consumed should be not more than one-third of the quantity used by the usual method in open kettles.

"I have finished my crop, and made the last 30 hogsheads with his apparatus, from a piece of my poorer cane. The production of molasses, I believe, is greatly reduced. The quality of the sugar is improved about one-half in value over that produced from the same cane in my set of kettles. I am satisfied that with the apparatus I shall make the next crop into white sugar, without the use of moulds and liquoring. The apparatus made at the rate of 18,000 lbs. per 24 hours, and boiled as much cane juice as my mill could furnish; and it is my opinion that it can produce a much greater quantity in the same period.

"The apparatus is very easily managed, and my negroes became acquainted with it in a short time. To produce the above quantity of sugar by the old process, I should have employed my two sets of kettles boiling together. My sugar mill and the apparatus were driven together by my engine, and I am convinced that the begassa of the previous year, which generally forms about a third of my fuel, would have been sufficient to have made my entire crop. The machine is elegant in its proportions, solid in its fixtures, and occupies a very small place in my sugar-house. I must confess that when I first contracted with Mr. R., I did not imagine that the apparatus would have been so complete. Every part is arranged with the greatest care, and is very durable. It worked, I may say, without any accident; and is ready for the next crop, as new and clean as it was the first day. I account as nothing a leather band which was temporarily employed by Mr. R. to drive the apparatus, instead of a connecting rod, which was then not ready.

"I am happy to add, that I consider Mr. Rillieux as completely successful, and as having satisfied every condition of the contract which he passed with me.

"I had many opportunities of admiring the ability and ingenuity of Mr. R., and I do not hesitate to declare that he is highly deserving of credit, and, in every respect, to the full confidence of the sugar planters of Louisiana.

"Very respectfully, yours,

"T. J. PACKWOOD.

"To the EDITOR *of the*
*New Orleans Bee.*"

32. The following report of a committee of the Agriculturists and Mechanics' Association of Louisiana upon sugars exhibited at the annual State fair, held by that association on the 5th of January, 1846, embodies information respecting the results not only of Rillieux's method, but also of other enterprises in that State.

The report is so succinct and complete, and the views taken in it by them seem to be so sensible, that I here insert it nearly entire; with the remark, however, respecting Mr. Morgan's experiments, that if the attempt to employ open steam pans for concentration to 25°, and a vacuum pan for striking, proved unsuccessful, as stated by the committee, it would, in my opinion, have certainly succeeded, had the cane juice been previously filtered through bone-black—an operation which, I have been informed, Mr. Morgan does not perform, but which is doubtless indispensable if we would obtain perfect results.

"SPECIAL REPORT ON SUGAR, FROM THE COMMITTEE FOR THE AGRICULTURAL DEPARTMENT.

"Amongst the samples of sugar which were exhibited at the fair, the committee has paid special attention, and has awarded premiums, 1st, to Packwood's; 2d, to Packwood & Benjamin's, 3d, to Verloin Degruy's; the first and second made by N. Rillieux's patent sugar-boiling apparatus, and the last by N. Rillieux's vacuum pan. The committee have been struck by the unrivalled beauty of the samples laid before the association. They considered it as their duty to make deep inquiries about a matter so closely connected with the interest and welfare of the entire State. They are now ready to report the result of their investigation on the new process of manufacturing one of the staples of Louisiana.

"The sugar which has been exhibited, coming from Packwood's plantation, is made from sirup without any additional clarification, and the strike is put in coolers and hogsheads as customarily; and this sugar, although termed brown, is white, being equal in color to the white Havana sugar: it has a larger and harder grain, and is perfectly free from molasses after having remained but six days in hogsheads.

"The molasses sugar from the same plantation is equal to the best prime brown sugar made by the old process.

"The samples from Packwood and Benjamin are of loaf sugar made directly from the cane juice. The sirup, without additional clarification, gives strike, which is put at once into moulds, and the sugar obtained is twice liquored. This sugar is perfect in color, the grain is beautiful, and may support competition with northern refined. The entire crop of 700 hogsheads, taken on this plantation this year, shows what unknown treasures the sugar planters may extract from the bottom of their soil.

"Two entire crops, taken from Packwood's plantation, fully prove the following facts: 1st, not a shade of coloring matter is developed from the beginning to the end of the boiling in N. Rillieux's patented apparatus; 2d, the quantity of molasses, which was customarily sixty gallons per hogshead of sugar, is reduced to fifteen gallons—the surplus is represented by an equivalent weight of sugar; 3d, this apparatus may be worked by the hands on the plantation, without any experienced sugar maker; 4th, the economy of fuel is such that the begassa is more than sufficient to take the crop. On considering this last circumstance, it becomes rather difficult to conceive how far our sugar production may be extended; for, impelled by their energetic and enterprising feelings, our race may, and doubtless will, turn every prairie and woodless land of the State into sugar cultivation.

"We are informed that, besides the two aforesaid plantations, several others will work the next crop by this new process. J. B. Armant, of St. James, one of the oldest and most respectable planters of the State; A. Lesseps, of Plaquemine; Verloin Degruy, of Jefferson; Chauvin and Levois, of St. Charles, are highly commendable for their enterprising spirit. After a careful examination of the facts, and obtaining on the two above plantations satisfactory evidence of the entire success of the apparatus, they did not hesitate to incur the apparently great expense which its adoption requires. We use the words apparently great expense, for the profit arising during a first crop fully repays the expenses. This is proved by the following table, which we lay before the association.

"It shows three different instances of plantations on old, ordinary, and new land; in other words, lands giving by the common process 40, 50, and 60 gallons of molasses per 1,000 pounds of sugar. It will be perceived that as the customary proportion of molasses is greater, the larger is the profit.

"We have based our calculations upon the quantity of cane juice necessary to obtain 1,000 pounds of sugar by the common process:

1st. OLD LAND—FORTY GALLONS OF MOLASSES PER ONE THOUSAND POUNDS OF SUGAR.

| | Common kettles. | | | | Apparatus (rough sugar.) | | | | Apparatus (liquored sugar.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Receipts.* | Lbs. | Galls. | Cents. | Dollars. | Lbs. | Galls. | Cents. | Dollars. | Lbs. | Galls. | Cents. | Dollars. |
| First sugar..... | 1,000 | .. | 5 | 50 00 | 1,000 | .. | 7¾ | 77 50 | 710 | .. | 10½ | 74 55 |
| Second sugar..... | .... | .. | .. | ..... | 300 | .. | 6 | 18 00 | 355 | .. | 8 | 28 40 |
| Cistern's bottom..... | 100 | .. | 2½ | 2 50 | | | | | | | | |
| Molasses..... | .... | 40 | 15 | 6 00 | .... | 15 | 15 | 2 25 | ... | 44 | 25 | 11 00 |
| | | Dolls | Dolls. | 58 50 | | Dolls. | Dolls. | 97 75 | | Dolls. | Dolls. | 113 95 |
| *Expenses.* | | | | | | | | | | | | |
| Cords of wood ..... | 3 | 1 50 | 4 50 | | 1 | 1 50 | 1 50 | | 1 | 1 50 | 1 50 | |
| Pounds of boneblack... | .... | .... | .... | 4 50 | 25 | 2½ | 62 | 2 12 | 25 | 2½ | 62 | 2 12 |
| Net proceeds on 1,000 pounds..... | ..... | | | 54 00 | ..... | | | 95 63 | ..... | | | 111 83 |
| Crop of 600,000 lbs.... | ..... | | | 32,400 00 | ..... | | | 57,378 00 | ..... | | | 67.098 00 |

2d. ORDINARY LAND—FIFTY GALLONS OF MOLASSES PER ONE THOUSAND POUNDS OF SUGAR.

| | Common kettles. | | | | Apparatus (rough sugar.) | | | | Apparatus (liquored sugar.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Receipts.* | Lbs. | Galls. | Cents. | Dollars. | Lbs. | Galls. | Cents. | Dollars. | Lbs. | Galls. | Cents. | Dollars. |
| First sugar | 1,000 | .. | 5 | 50 00 | 1,080 | .. | 7⅞ | 83 70 | 750 | .. | 10½ | 78 75 |
| Second sugar | .... | .. | .. | ..... | 390 | .. | 6 | 18 00 | 375 | .. | 8 | 30 00 |
| Cistern's bottom | 100 | .. | 2½ | 2 50 | | | | | | | | |
| Molasses | .... | 50 | 15 | 7 50 | .... | 15 | 15 | 2 25 | ... | 47 | 25 | 11 75 |
| | | Dolls. | Dolls. | 60 00 | | Dolls. | Dolls. | 103 95 | | Dolls. | Dolls. | 120 50 |
| *Expenses.* | | | | | | | | | | | | |
| Cords of wood | 3 | 1 50 | 4 50 | | 1 | 1 50 | 1 50 | | 1 | 1 50 | 1 50 | |
| Pounds of boneblack | .... | .... | .... | 4 50 | 25 | 2½ | 62 | 2 12 | 25 | 2½ | 62 | 2 12 |
| Net proceeds on 1,000 pounds | ..... | | | 55 50 | ..... | | | 101 83 | ..... | | | 118 38 |
| Crop of 600,000 lbs | ..... | | | 33,300 00 | ..... | | | 61,098 00 | ..... | | | 71,028 00 |

3d. NEW LAND—SIXTY GALLONS OF MOLASSES PER ONE THOUSAND POUNDS OF SUGAR.

| | Common kettles. | | | | Apparatus (rough sugar.) | | | | Apparatus (liquored sugar.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Receipts.* | Lbs. | Galls. | Cents. | Dollars. | Lbs. | Galls. | Cents. | Dollars. | Lbs. | Galls. | Cents. | Dollars. |
| First sugar..... | 1,000 | .. | 5 | 50 00 | 1,160 | .. | 7¾ | 89 90 | 790 | .. | 10¼ | 82 95 |
| Second sugar..... | .... | .. | .. | ..... | 300 | .. | 6 | 18 00 | 395 | .. | 8 | 31 60 |
| Cistern's bottom..... | 100 | .. | 2½ | 2 50 | | | | | | | | |
| Molasses..... | .... | 60 | 15 | 9 00 | .... | 15 | 15 | 2 25 | ... | 49 | 25 | 12 25 |
| | | Dolls. | Dolls. | 61 50 | | Dolls. | Dolls. | 110 15 | | Dolls. | Dolls. | 126 80 |
| *Expenses.* | | | | | | | | | | | | |
| Cords of wood..... | 3 | 1 50 | 4 50 | | 1 | 1 50 | 1 50 | | 1 | 1 50 | 1 50 | |
| Pounds of boneblack.. | .... | .... | .... | 4 50 | 25 | 2½ | 62 | 2 12 | 25 | 2½ | 62 | 2 12 |
| Net proceeds of 1,000 pounds..... | ..... | | | 57 00 | ..... | | | 108 03 | ..... | | | 124 68 |
| Crop of 600,000 lbs... | ..... | | | 34,200 00 | ..... | | | 64,818 00 | ..... | | | 74,808 00 |

NOTE.—The dry begassa from the cane giving one thousand pounds of sugar is, as fuel, more than equivalent to one cord of wood; and when the first is used with the apparatus, it dispenses altogether with wood.

"In condensing the above we find that the profit on a crop of 600,000 pounds derived from the new process, and above the common, is as follows:

| | Rough sugar. | Liquored sugar. |
|---|---|---|
| 1st. Old land | $24,978 | $34,698 |
| 2d. Ordinary land | 27,798 | 37,728 |
| 3d. New land | 30,618 | 40,608 |

"We are informed that the advances incurred by the planters to take a yearly crop of 600,000 pounds by this apparatus are $20,500 to obtain rough sugar, and $24,500 to make liquored sugar.

"This, certainly, is a matter worthy of a minute investigation, and we beg every one to go and ascertain for himself facts so highly deserving notice. We hope, at the next fair, a model of this new apparatus will be exhibited by the inventor.

"The sugar made by Verloin Degruy, esq., of Jefferson, was also specially considered by this committee. On his plantation the cane juice is boiled in the common set ef kettles; and when the sirup reaches 25 or 28 degrees, it is finished and granulated in N. Rillieux's vacuum pan. The sugar thus made is excellent in color, and of a coarse and very bright grain. It must be classed ahead of prime brown sugar, and we did not hesitate to award it a premium *ex equo* with Packwood's sugar, although its intrinsic value is much lower, because the expense is small (not above $3,000) and the process exceedingly simple. In relation to this, we publish the following letter written by Mr. Verloin Degruy himself:

*'To the committee for the agricultural department of the Agricultural and Mechanics' Association of Louisiana:*

PARISH OF JEFFERSON,
*January* 9, 1846.

'GENTLEMEN: I reply to your inquiries about N. Rillieux's vacuum pan used on my plantation:

'The sugar which has been exhibited at Baton Rouge fair, held January 6, 1846, is the average sample of my crop taken up by N. Rillieux's vacuum pan, and it is, compared with sugar made by the common process, one cent at least in advance. I have been offered, and have refused, 6⅝ cents for my sugar. I calculate that the profits derived from this machine fully repay this year its purchase price. During all the crop I had this vacuum pan very easily managed, and it worked satisfactorily and without interuption, with steam from my common boilers and water from my pond; and I must say, also, that I highly recommend Mr. N. Rillieux to the public patronage, on account of his full and plain compliance with every term and condition of the contract which he passed with me.

'I am now making very fine sugar with canes so sour, that I believe it will be impossible to make sugar with them by the common

process; and the quantity of molasses is scarcely more, if any, than with my best canes before the frost.

'Respectfully, yours,

'F. VERLOIN DEGRUY.'

"We must add, as a remark worthy of great interest, especially for the sugar planters of our northern parishes, that Mr F. Verloin Degruy obtained a very good sugar at the beginning of his crop with cane juice at 6 saccharine degrees; and that on the three above plantations the sugar *stood equally good with acid juice from frozen canes, which would have produced nothing but molasses by the common process.**

"In conclusion, we must say that in our opinion N. Rillieux's patent sugar-boiling apparatus and vacuum pans deserve special notice, as well for the ingenuity displayed in their arrangement as for their perfect construction, by Merrick & Towne, owners of the Southwark foundry, in Philadelphia, and assignees of N. Rillieux's patent.

"We consider it as our duty, before ending this report, to throw a retrospective view on several improvements tried this year in the art of manufacturing sugar.

"We have heard something said in very laudatory terms of a new process of clarifying the cane juice, from the honorable F. Garcia, of St. John the Baptist, jointly with Bertrand, apothecary of New Orleans. We report this only as a rumor, for the above gentlemen did not think proper to explain their process or make an exhibition of it at the State fair. We will say the same also in relation to Debreton's mode of clarifying the cane juice. In conclusion, we feel we are bound to add that planters must guard themselves against any system that includes secret clarifying agents and be wary of making use of sugar of lead or sulphate of zinc, which are poisons endangering the public health; and not being necessary to produce the best quality of sugar, there can be no apology for their use.

"During the past season there were several attempts to introduce new machinery. Amongst them there were several vacuum pans: one put up on Mr. Maunsel White's plantation, in Plaquemine, but which was not ready in time. The delays have endangered a great part of his crop. Another vacuum pan on Judge Butler's plantation, at Grand Caillou, has given sugar of a very large grain; but the owner did not use it for his whole crop, and made only a few hogsheads of sugar with it, for reasons which we are unable to to assign. At Thomas A. Morgan's, of Plaquemine, (the first planter who ever boiled sirup by vacuum pans in this State,) trials have been made to concentrate the cane juice up to 25 degrees by steam. He has set up three open steam kettles and a new vacuum pan for that purpose, at an expense of about $8,000, and we regret to say that a planter of such enterprise did not succeed in his expectation.

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*See Appendix notes F and H.

"Several open pans of Mapes' construction, and from Stillman's works, have been used. These pans work well, but it remains difficult to decide if they present any advantages over the common worms, which are cheaper and easier to be kept in good order.

"The honorable Judge P. A. Rost, in his oration delivered on the 13th of May last, mentioned a new apparatus, embracing all that had been found valuable in the others, then in course of construction by Stillman & Co., of the Novelty Iron Works, New York, for Mr. Valcour Aime of St. James. We regret to say that the trial of this enterprising gentleman, and of which so great a profit was expected for our country, has proven unsuccessful. Let us hope that with the alteration which he contemplates at present, he will succeed to take in his next crop. We are informed that he has expended this year $22,000 for an apparatus to make 18 hogsheads a day, and that the contract for the new alterations proposed amounts to $8,000. Rarely do we find a planter ready to go into such expensive trials for the welfare of the community; and we do not hesitate to give him all the encouragement on behalf of our association; but at the same time, let this example remain as a striking warning to our planters. Is it to their interest to make such trials—always costly, often ruinous? We do not recommend such pursuit. Here is the case of a planter known in the entire State for his practical knowledge, and who may be ranked amongst the most talented men of our community, expending $30,000, and being yet uncertain of the result. Is it prudent to follow the same course? shall we run the chance of losing large advances, besides a part of our crop ?*

"In our opinion, the planters are to be governed by other rules: they, we believe, must adopt what has already been tried, and nothing but what has been proved unquestionably successful.

" We congratulate our country on the spirit of enterprise which prevails. The competition evinced in the improvement of the manufacture of sugar shows energetic feelings amongst our planters; and if on the one hand we recommend prudence, let us also encourage a spirit which will turn to the benefit of the community, and will prove more and more economical and profitable to the great staple of Louisiana."

33. Although the application of the principle of employing the latent heat of vapor to the particular use of manufacturing sugar with economy of fuel was first made by Dégrand and Rillieux, and by means of very different forms of apparatus, yet the principle itself is neither one lately discovered, nor but recently applied in other branches of industry. It has long formed a part of the established science of applied physics; and from a standard work,† which has been generally and familiarly known for nearly twenty years, I translate the following passages:

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* See Appendix, note H.

† Péclet, Traité de Chaleur, t. 2, p. 300: Paris, 1828.

"Under certain circumstances we may make use of a part of the latent heat of the vapor which is disengaged to heat liquids contained in other boilers, and produce in them a gentle evaporation. It is this arrangement that I designate by the name of an apparatus of double effect, *appareil à double effet*.

"We may likewise employ the latent heat of the second vapors for heating other vessels; but the second boilers must then of necessity be close, and the liquid must attain in them the temperature of ebullition. Hence the liquid in the first boilers must be subjected to a pressure greater than that of the atmosphere.

"In all the large systems of evaporation where the work is continuous, such as those of salines, for the soda factories, &c., nine or ten parts of steam for every one of coal may be disengaged by a suitable arrangement; whereas generally five or six parts only is the result obtained."

The brewers have long applied the above described principle in the evaporation of wort.* But its combination with a vacuum pan, and heating by steam, as well as its application to the sugar industry, was certainly the invention of M. Dégrand and Mr. Rillieux, independently of each other. The idea of the *successive* use of latent heat is, however, carried out distinctly and completely only by Rillieux; and the use of latent heat constitutes apparently only a secondary feature in Dégrand's serpentine tube, the principal office of which is condensation within by the cooling influence of evaporation by exposure of a large surface, moistened with a thin film either of water or saccharine juice, to the action of the air.

The advantage of Rillieux's mode of successive employment of the same heat may be readily shown by a simple calculation. As we have already stated, the total amount of heat contained in steam of any pressure is equal to 1212° Fahrenheit. If, therefore, the quantity of water converted in the engine boiler, at the temperature of 250° Fahrenheit, into high steam of the pressure of two atmospheres, be represented by $a$, we shall have

$$1212\ a = 250\ a + 962\ a.$$

In condensation this steam will, therefore, retain, and either restore to the engine or carry off by a waste pipe, the quantity $(250\ a)$ of free heat; while the $962\ a$ of latent heat will be imparted to the first of the series of evaporating pans.

For the sake of simplicity, we will suppose the series of pans to contain water instead of cane juice, and that the quantity in each is equal to that originally converted into high steam, and which we have denoted by $a$ in the above equation; also, that the pressure in each pan is the same, and equal to the ordinary atmospheric pressure. Let $x$, $x'$, $x''$, $x'''$ represent respectively the quantities of

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*See Péclet, Traité de Chaleur, t. 2, p. 502; also, Ure's Dictionary of Arts; article, Beer.

water which remain unevaporated in the boilers, and $y$, $y'$, $y''$, $y'''$, the portions evaporated, then we shall have, for the first pan,

$$962\ a = 212\ x + 1212\ y,$$
$$a = x + y;$$

Hence, by elimination,

$$x = 0.25\ a;\ \text{and}\ y = 0.75\ a.$$

Three-fourths of the contents of the first pan will therefore be converted into steam, and will pass over into the heating tubes of the second boiler. In these tubes this steam will be condensed, and the portions of heat retained and communicated will be expressed by the first and second terms of the last member of the equation :

$$1212\ y = 212\ y + 1000\ y.$$

We have, therefore, $1000\ y = 750\ a$ for the value of the heat imparted to the contents of the second boiler.

By similar reasoning, we obtain :
For the second boiler,

$$750\ a = 212\ x' + 1212\ y';\ x' + y' = a;$$

and therefore,

$$x' = 0.462\ a;\ y' = 0.538\ a.$$

For the third boiler,

$$538\ a = 212\ x'' + 1212\ y'';\ x'' + y'' = a;$$
$$x'' = 0.674\ a;\ y'' = 0.326\ a.$$

And lastly, for the fourth boiler,

$$326\ a = 212\ x''' + 1212\ y''';\ x''' + y''' = a;$$

which give

$$x''' = 0.886\ a;\ y''' = 0.114\ a.$$

The total amount of water evaporated will be expressed by the equation:

$$S = y + y' + y'' + y''';$$

or, by substitution and addition,

$$S = 1.728\ a.$$

If three boilers only be used, we shall have

$$S = 1.614\ a.$$

And if but two, then

$$S = 1.288\ a.$$

From the value obtained for $y''$ it follows that the steam devel-

oped in a fifth boiler would be a negative quantity; or, in other words, the heat imparted to a fifth boiler would be insufficient even to heat its contents to 212° Fahr. This is also evident from the fact that the amount thus imparted would be only 114°. A fifth boiler would, therefore, add nothing to the amount of water evaporated under atmospheric pressure.

In the preceding calculations I have supposed the contents of each pan to be, before heating, of the temperature indicated by the zero of Fahrenheit's thermometer, a temperature much below that which cane juice would ever be subjected to in sugar-making countries. Nor has the effect of diminished pressure produced by an air-pump, or by the condensation of escaping vapor, been taken into consideration in them. For both of these variations in the circumstances under which the operation is actually performed, corrections must be applied which would considerably augment the calculated result; other corrections are also required for heat lost by radiation, by the conducting and absorbing influence of the metal and of other bodies, by currents of air, &c.; for which corrections no accurate values can be assigned, except by experiment in each particular case. Hence, we may justly infer that the probable value obtained by the calculation given above approximates nearly to the actual effective result, as the corrections to be applied compensate each other.*

## Section V.—*On crystallization.*

1. Substances which pass from the liquid to a solid state usually assume regular geometrical forms. And this symmetrical arrangement of the particles, or crystallization, is, therefore, not the result of accident, but of certain arranging forces, which operate with perfect regularity, and depend upon the chemical nature of the substance itself. The general laws which those forces obey, and the circumstances which modify their action, are important facts not only to theoretical science, but to all branches of industry, the successful results of which depend upon the proper formation of crystalline bodies. A knowledge of the subject of crystallization is, therefore, of such value to the sugar manufacturer that I have thought it proper to enumerate succinctly the principal results which practical experience and chemical science have established, although they may be found fully stated and discussed in the more complete treatises on chemistry.†

The more gently and slowly crystallization takes place the larger and more perfect will be the crystals. If it occur rapidly, the crystals will therefore be small and confused.

While repose causes crystallization to be both slow and regular, mechanical agitation accelerates it, but renders the crystals minute and irregular. Hence rock candy is made by allowing sirup

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* See Appendix, note H.

† See Berzelius, Traité de Chimie; or Dumas, Traité de Chim. Appliq. aux Arts.

slightly concentrated to evaporate gently in a stove, while fine-grained loaf sugar is the result of agitation and rapid solidification.

Foreign substances, especially those of a porous nature, encrust themselves with crystals in crystallizing solutions. Hence the use of threads in the manufacture of rock candy; and similarly, the manufacturers of blue vitriol make use of sticks, upon which the salt crystallizes, and by which it is then readily removed.

Crystals already formed act even more energetically than porous bodies; and such is their influence, that we may obtain from a solution of two salts either the one or the other, at pleasure, by immersing a crystal of the salt we wish to separate. If, for instance, we dissolve two parts of nitre and three of sulphate of soda in five of warm water, and pour the solution into two flasks, filling them each; then if we put a crystal of nitre into one, and a crystal of sulphate of soda into the other, and place them both in a mixture of water and powdered ice, there will be formed in the one only crystals of nitre, and in the other only crystals of sulphate of soda.

Crystals of larger size and modified form may be made by the increase produced by immersion in saturated solutions; and large crystals will even grow at the expense of smaller ones in the same solution, if exposed to changes of temperature. When the temperature rises, the solution becomes stronger, by dissolving a portion of the crystals; but when it cools again the matter thus taken up will be deposited chiefly upon the large crystals; so that, after a while, the smaller crystals will entirely disappear.

In solutions allowed to crystallize quietly, crystals form chiefly at the bottom, and not uniformly throughout the liquid. The reason for this is, that when the solid matter is deposited, the liquid which was combined with it is set free, and, being of less density than the rest of the solution, it rises to the top and gives place to another saturated portion; this, in turn, deposites part of its solid matter, and ascends as the former. If we look through a crystallizing solution, we may observe this ascending motion of the particles, and distinct currents rising from the larger crystals.

All crystals which form in aqueous solutions enclose a portion of the solution, or mother-water, mechanically, between their molecules: if the solution contain other substances, this will render the crystals more or less impure. Hence it is often necessary to purify substances by repeated crystallization. The larger the crystals, the more of the mother-liquor will they thus absorb. For this reason crude nitre, alum and sugar, are purer when, by rapid crystallization, they have formed in small grains.

Many substances in crystallizing also combine chemically with a portion of water. This water enters into them very differently from mere water of solution; for it becomes solid, and is always in definite proportion. It is usually called *water of crystallization* or *water of combination*. The manner in which water unites with quicklime in slacking furnishes an illustration of this combination; and the development of heat, in a greater or less degree, is generally an accompanying phenomenon.

2. The forces above mentioned, which tend to solidify and arrange particles of matter in definite geometrical forms, and which are often spoken of as the forces of *cohesion*, are opposed by the antagonist force of heat. In some instances, as in melted metals, heat acts directly to produce the liquid state; in others, as in aqueous solutions, it is indirectly the cause of the fluidity of the dissolved matter. That this is so is evident; because at the temperature of 32° Fahr. water itself solidifies, and gives off 140° of latent heat.

If solid bodies be dissolved in water, the force which causes them to unite and form one homogeneous solution renders the evaporation of the water more difficult than that of pure water alone. Such a solution, therefore, boils at a temperature the more elevated in proportion as the affinity of water for the dissolved substance is greater. If this affinity be entirely saturated, then will the boiling point be stationary; but if the affinity increase with the temperature, the boiling point will also vary proportionally. Thus a perfectly saturated solution of common salt boils at 240° Fahr., and one of nitre at 263° Fahr.; while aqueous solutions of sugar or of sulphuric acid, etc., boil at higher temperatures in proportion as they are more concentrated.

3. Heat increases the dissolving power of water for most solid substances; if, therefore, a hot saturated solution be allowed to cool, crystals will generally be deposited in consequence of the excess of matter soluble in hot water, but insoluble at low temperatures. If water be evaporated by heat from a weak solution until it becomes saturated, upon allowing it to cool, crystals will be formed by reason of the loss of water requisite to hold them in solution. The evaporation and crystallization of saccharine juices furnish an instance of this latter mode of operation; the proper performance of which constitutes, indeed, the whole art of the sugar boiler.

Impure solutions crystallize very differently from those which are pure. In muddy or turbid solutions, the impurities of which are mechanical, crystals are usually larger, and often of different form from those which form in clear solutions. These mechanical impurities also usually become enclosed in the crystals. If urea be added to a solution of common salt, it will yield octahedral instead of cubic crystals.

The above general facts, together with a knowledge of the solubility of sugar in water at different progressive temperatures, will be sufficient to enable us to form clear and rational ideas upon the subject of the crystallization of cane-sugar, and the proper method of conducting the operations relative thereto by sugar manufacturers and refiners.

4. In most books on chemistry, it is usually stated that "cane sugar is soluble in one-third of its weight of cold water, and to any extent in hot water." This is untrue, as I have already stated,* if

* See Senate Doc. No. 165, 2d session 28th Congress, page 165.

by "hot water" be meant "boiling water," or water heated to 212° Fahrenheit, the signification which the words would ordinarily be supposed to possess. But if this phrase be intended to convey an idea of the results we obtain when we evaporate a saturated solution of sugar, it may be admitted as an inaccurate and vague expression of truth. If we unite common salt and water at different degrees of heat, in such a manner as to form saturated solutions, we will find that the water dissolves a greater quantity of salt as the temperature rises, until we reach 240° Fahrenheit, when the solution boils and attains its maximum degree of saturation, the water being united with 40.38 per cent. of its own weight of salt. Any further addition of heat only serves then to drive off part of the water, in the form of steam, and to deposite *in a solid form* the salt with which it was united. A very different result is obtained if we heat a pure solution of sugar—one, for instance, which contains about 66 per cent. of sugar. Owing to the union of the sugar and the water, this solution will not boil until it reaches the temperature of 220° Fahrenheit, at which temperature the affinity of the water for sugar will be so much increased, that instead of the sugar which was united with the steam evolved being deposited in a solid form, it will remain combined with the unevaporated water. The solution will thus become more concentrated, and being now united by a more powerful affinity, it will have a more elevated boiling point. Further concentration, increased affinity, and a more elevated temperature of ebullition, ensue; and to this continuous action there is no definite limit or point of saturation; so that if the evaporation be pushed to the temperature of 270° Fahrenheit, we obtain a sirup so viscid, that if allowed to cool, the particles of sugar cannot arrange themselves in crystals, and the whole mass congeals in the form of a transparent amorphous substance. In this state it is prepared by the confectioners, and commonly known as *candy*. From the sirup which thus solidifies at 270° Fahrenheit all the water of solution has not, however, been evaporated; for it is composed of 10 per cent. of water united with 90 per cent. of sugar. If we continue to increase the heat, with the view of driving off the rest of the water, we soon attain a temperature at which decomposition of the sugar itself takes place.

That the forces which tend to arrange the particles of sugar in *candy*, made, as above described, from sirup concentrated to 270° Fahrenheit, are only prevented from forming crystals by the very viscid nature of the solution, and the consequent impeded motion of its constituent molecules, is proved by a singular change which takes place afterwards in the internal structure of the candy. When first made, it is beautifully transparent; but after some time it becomes opaque. If we examine the alteration closely with a microscope, we readily perceive that it consists in crystallization, and that the crystals proceed from the external surface to the centre. The cause of this change has been supposed by M. Dumas to be a loss of heat. I should rather ascribe it to the evaporation of part of the water of solution retained in solidification. Whatever be the cause, the fact is unquestionable, and familiarly known to con-

fectioners, who endeavor to preserve the transparency of their candy by adding vinegar to it. The change is thus retarded, but not prevented.

5. If, instead of continuing the evaporation to 270° Fahrenheit, it be arrested at about 235°, then, when the sirup is allowed to cool, a large proportion of the sugar crystallizes in small detached grains. At this temperature the sirup is composed of about 19 parts of water, united with 100 parts of sugar: on cooling, the water will retain about 38 parts of the sugar, and form with it a saturated solution, while the remaining 62 parts of sugar will separate in crystals; from these crystals the sirup will then readily drain.

To attain with certainty the result just described, constitutes the whole art of the sugar boiler. The proper degree of evaporation is technically known as the *striking point*, and the concentrated sirup is called *the strike;* while *striking* is the term applied to the operation of removing the contents of the evaporating pan into the *cooler*, a large vessel for their reception, in which the sirup is allowed to cool and crystallize.

6. The thermometer is used for the determination of this striking point only by those who boil in vacuo, and by some who employ open pans; and most of the sugar manufacturers depend entirely upon certain signs or appearances, which become familiar to the workmen by practice. The use of a thermometer is objected to by many, for two reasons: first, that it does not indicate changes with sufficient rapidity; and, secondly, that sirups of different degrees of purity require different temperatures. Whatever may be the force of these objections with respect to dependence upon a thermometer alone, they certainly have no meaning when applied to the combined use both of thermometric indications and the above mentioned signs. The thermometer furnishes a ready and perfect means of knowing whether the concentration approaches the striking point; while, if sirups of proper purity be operated upon, it also shows *exactly* when they are evaporated to any fixed degree. The objection that the temperature varies for different sirups, serves, therefore, rather to confirm the propriety of using thermometers than to detract from their value, since, by virtue of this very variation, they serve as checks upon the preceding operations, and may be employed to detect the insufficient or excessive use of lime, injury by fermentation, etc.; and although, in working second products, as in ordinary bastard sugar, the temperature of the striking point varies from that required by pure sirups, yet this will also take place approximatively at a mean degree; any considerable variation from which will indicate some unusual change. The objection of want of sufficient sensibility is one of little value; for the construction of thermometers is now so well understood, that they may readily be made of any required degree of delicacy.

I must confess that I am skeptical with reference to the force, and even the honesty, of objections urged against the use of an instrument so perfect as the thermometer, and in favor of entire depend-

ence upon mere indications of touch, etc., established by familiar routine. The prejudices of ignorant workmen are always strong and obstinate, with reference to any change in operations which they have had the trouble to learn, and frequently to perform; and it is, therefore, sufficient cause with them for condemning any improvement that it is something new, no matter how valuable, unless it be of the nature of labor saving machinery, to indulge them in laziness. This remark, though true for all branches of industry, is, perhaps, for none more so than for the sugar manufacture, which has been confided chiefly to negroes, and scarcely less stupid and ignorant white men.*

For recommending the use of the thermometer, there is, however, a reason of great importance, apart even from the question of its fitness for determining exactly the proper striking point; and which reason is, that it furnishes the *only* means of obtaining definite and precise knowledge with reference to the evaporation of concentrated sirups. The planter or refiner who would understand the subject, and obtain comparative results, must employ the thermometer.

In one of the best and largest refineries of the United States, formerly conducted upon the system of evaporating in open pans, the thermometer was employed for regulating the evaporation of the sirup.† The instrument used was two or three feet long, so as to give very large degrees, that could be read through the vapor. It was suspended so that its bulb, protected by a metallic ring, was situated in the syrup, while its scale was defended by a case of wood. The striking point was usually 230° to 240°; the poorer the sugar, the higher the heat. This refinery has since been changed, and is now conducted upon the system of vacuum pans.

7. M. Dutrone (who seems to have prosecuted his investigations with exactness of method and inquiry creditable in the highest degree, especially at his day) was fully sensible of the value and importance of the thermometer to the sugar manufacturer. After having practically acquainted himself with the operations in use, even to their most minute details, and conducted an estate upon

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* The following criticism upon the preceding remarks is extracted from an article written by Mr. Valcour Aime, which was published in De Bow's Review, vol. 5, page 255:

"The thermometer is advantageously and generally used, to judge of the state of concentration of the syrups, in open evaporating pans, heated by steam; but the use of that instrument to ascertain the striking point, in the manufacture of vacuum pan sugar, is a practice not to be thought of. Syrup coming from the blow tubs and leaf filters at 32° Beaumé, is often at 150° Fahrenheit, when put into the pan. It rises in fifteen minutes to 160°, and may be kept at that point for several hours, until it reaches the proper degree of evaporation; indeed, if the boiler has at his disposal a large supply of water, he may, by the injection of cold water, lower the temperature while the concentration is progressing, and this is commonly done when it is considered desirable to obtain a large and solid grain. The thermometer is employed in the vacuum pan to keep the boiler advised of the heat he has in it, and enable him, in conjunction with the air glass or barometer, to regulate his pan as to steam and water; for striking, the test by the touch with the proof stick is the only one that can be depended upon."

† See Silliman's Report on Sugar, in compliance with a resolution of the House of Representatives, January 25, 1830, page 105.

similar methods, he remodelled the whole system, with the most satisfactory results. He formed and employed a table, showing the state of concentration progressively for each degree of Reaumur's scale; and he strongly recommends its use, in connexion with the signs familiar to experienced workmen. Dutrone's table was based upon experimental researches; and I therefore give it below, modified, however, by substituting the corresponding degrees of Fahrenheit's thermometer for those of Reaumur, and decimal values, at each degree of concentration, in place of the less simple though equivalent expressions in pounds, ounces, etc., used by Dutrone.

At 22° Reaum., (81°.5 Fahr.,) it requires (according to Dutrone) three parts of water and five parts of sugar to form a saturated solution. He therefore used sirups, made by dissolving 100 pounds of sugar in 60 pounds of water for his experiments, from which he constructed the following table.

| Degrees of thermometer, Fahrenheit. | Per cent. of the water evaporated. | Per cent. of the water which still remains in combination. | Per cent. of the sugar which separates in crystals. | Per cent. of sugar left, united with water in form of sirup. |
|---|---|---|---|---|
| 219 | 0.00 | 100.00 | 0.00 | 100.00 |
| 221 | 8.00 | 92.00 | 8.00 | 92.00 |
| 223 | 19.30 | 80.70 | 19.25 | 80.75 |
| 225 | 30.00 | 70.00 | 30.00 | 70.00 |
| 228 | 40.70 | 59.30 | 41.00 | 59.00 |
| 230 | 52.00 | 48.00 | 52.00 | 48.00 |
| 232 | 56.30 | 43.70 | 56.00 | 44.00 |
| 235 | 60.30 | 39.70 | 60.30 | 39.70 |
| 237 | 63.40 | 36.60 | 63.25 | 36.75 |
| 239 | 65.40 | 34.60 | 66.20 | 33.80 |
| 241 | 69.90 | 30.10 | 69.15 | 30.85 |
| 243 | 72.10 | 27.90 | 72.05 | 27.95 |
| 246 | 75.00 | 25.00 | 75.00 | 25.00 |
| 248 | 77.45 | 22.55 | 77.45 | 22.55 |
| 250 | 81.50 | 18.50 | 80.30 | 19.70 |
| 252 | 83.50 | 16.50 | 83.20 | 16.80 |
| 255 | 85.00 | 15.00 | 85.00 | 15.00 |
| 257 | 87.00 | 13.00 | 87.25 | 12.75 |
| 259 | 88.50 | 11.50 | 88.40 | 11.60 |
| 261 | 90.10 | 9.90 | 90.05 | 9.95 |
| 264 | 92.00 | 8.00 | 91.25 | 8.75 |
| 266 | 92.90 | 7.10 | 92.45 | 7.55 |
| 268 | 94.10 | 5.90 | 94.10 | 5.90 |
| 270 | 95.30 | 4.70 | 95.20 | 4.80 |
| 273 | 97.35 | 2.65 | 97.00 | 3.00 |
| 275 | 98.20 | 1.80 | 98.10 | 1.90 |
| 277 | 99.15 | 0.85 | 99.10 | 0.90 |
| 280 | 100.00 | 0.00 | 100.00 | 0.00 |

8. It is evident, upon inspection, that the first and third columns of this table, and therefore the second and fourth also, are nearly

identical. They should be exactly so; for the quantities of crystalline matter separated from a saturated solution depend upon, and are proportional to, the water evaporated. The slight differences from identity which occur in some of the corresponding terms, and which in no instance exceed fractional values, confirm the accuracy of Dutrone's work; for in all experiments errors of weighing, etc., must occur, and the small differences referred to, therefore, furnish evidence of the faithfulness of the observer, and of the truth of his statement that the table is composed of actual experimental results. Had Dutrone obtained only one column by experiments—the first, for instance—and then calculated the other three from the first, as he might have done, the above mentioned approximative identity would have been exact. But by expressing his results in gross weight of pounds, ounces and grains, and using for his solutions sixty pounds of water, and one hundred pounds of sugar, the identity is concealed, which appears at once when we employ decimal values, or per cent. of the original quantities of water and sugar combined.

9. No other instrument than the thermometer has yet been employed in open pans for ascertaining the precise degree of concentration at which the evaporation of sirups should terminate. The areometer of Beaumé answers very well for lower degrees of density, although that instrument is not to be depended upon for accuracy, within one or two degrees, by reason of erroneous principles of construction; but the viscosity of concentrated sirups impedes the motion of any hydrometer, however exactly constructed, to such an extent that no instrument of the kind is of any use for determining the striking point. This determination must therefore be made either by the thermometer, or by the signs known to the workmen, or by the two combined. "The use of the thermometer," says Dutrone,* "in the striking (*cuite*,) far from excluding the proof of the fingers, which is very convenient, serves, on the contrary, to cast light upon it, and to render the practice less uncertain; it gives to the refiners fixed and relative terms, upon which they may depend with security."

10. I have sought to acquaint myself with the signs employed by sugar boilers, practically, as well as from oral and written descriptions of them; and from what I have heard as well as seen of them, I have become fully convinced that some of these signs are very useful and delicate, and that all of them are more or less valuable. I would not, therefore, be considered as underrating their importance in recommending the thermometer to be used in connexion with them; nor as condemning their use, if I censure an ignorant and implicit dependence upon them alone.

11. In the island of Cuba the Spanish sugar maker judges of the

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* See Précis sur la Canne, page 182.

state of concentration by three things: first, by the appearance of the bubbles formed by the escaping steam; when these become nearly of equal size, and uniformly distributed over the surface of the boiling sirup, he concludes that the evaporation is nearly sufficient; secondly, if, upon dipping his copper ladle into the sirup and removing it bottom upwards, the sirup covers it thickly and falls slowly in distinct drops, this proof confirms the first; and, lastly, when by the preceding proofs it is known that the sirup is concentrated nearly to the desired point, then he resorts to the *proof by the touch*, as practised elsewhere; but he judges not only by the forms the thread of sirup assumes in breaking, but also by the sound produced when the finger is suddenly separated from the thumb, and the sirup between them torn quickly apart. The shorter the sound, the more concentrated is the sirup. When the thread breaks, and the retracting portion curls itself into a spiral, the sirup is considered of the proper degree for making clayed sugar; for muscovado sugar it is boiled to a slightly further degree. The workmen, however, seem to have no clear ideas respecting the nature of the operation, and speak loosely of it, as one of cooking —like those of frying, stewing, boiling, etc., familiarly practised in the preparation of food. So far from regarding it merely as evaporation of water, many of them, by reason of the crystallization which takes place subsequently as the sirup cools, think that some change is produced by the heat upon the sugar in the juice, by which it becomes hardened, as albumen is coagulated in a hard-boiled egg. From ideas so crude, no union of knowledge and practice can possibly result; and the success of the sugarmaker depends, therefore, upon the infallibility of the empirical rules he blindly follows.

12. The *proof by the touch* above mentioned is used, I believe, alike by the refiners and the sugarmakers of all nations, both in Europe and America, and with very slight modifications. A small portion of the sirup is taken for trial between the index finger and the thumb: when it is cool, the finger is separated from contact with the thumb, and the sirup examined by placing it between the eye and the light. At different degrees of concentration the following indications successively occur;* "1st, two drops separate—that on the thumb and below is the larger; 2d, the drops become nearly equal, and do not separate until the fingers are drawn more widely apart; 3d, by the separation of half an inch a thread is drawn out, which finally breaks below; the end of the thread becomes claviform, and it rises slowly towards the finger; 4th, the same thing occurs at a greater distance; the end of the thread is folded back, and gives to the thread the shape of a ribbon or long strip, which rises more rapidly than before; 5th, after a greater separation of the fingers the thread breaks, being very fine at the end, which turns aside and twists up like a cork screw. It does

* See Dictionnairie de l'Industrie, p. 407. Paris, 1841.

not fold itself upon the rest of the thread, as before, and the thread does not increase in volume except by the cohesion which draws the particles towards the finger, which is the only adhering point. A little more concentration prevents the thread from shrinking at all upon itself."

In the United States the manufacturers of sugar from cane juice use the *proof by the touch*, and consider sirup sufficiently concentrated when the broken thread curls up in the form of a cork-screw, or at the fifth of the degrees above described. They sometimes use the thermometer, and the temperature to which they boil is usually about 236° Fahr. The proof by dipping the copper ladle into the sirup is also generally employed; a thick coating of sirup, which drains off slowly, and presents a granular appearance, being the sign that the operation is finished.

The refiners who use open pans rely generally upon the *proof by the touch*, and sometimes a thermometer; but the former is preferred.

In the British West Indies the *proof by the touch* is not only that chiefly depended upon, but the names of the evaporating pans have even been taken from it, the pronunciation of the word *touch* by the African slaves being *teache*. They also employ the proof by dripping from the ladle.

13. The French seem to have bestowed upon the indications employed by the workmen more attention than other nations. The technical terms or names given by them to these indications are numerous, and these constitute, when practically understood, the sum of the knowledge of the French sugar boiler. Dutrone's account of the terms in use by the French refiners of his time, and his critical remarks upon them, seem to be so clear and judicious that I here embody a translation of them.*

"The refiners, both of America and Europe, have never had a just idea of the action of heat in the concentration, (*cuite.*) They observe well some of its effects, to which they give various names; but they have no knowledge of the nature of its action, which they have often denoted by the word *cuisson*, (candying,) a term applied only to the principal operation in the art of the confectioners. This operation (*cuisson*) is comprised between the limits of 110° and 120° of Reaumur's thermometer, (280° and 302° Fahrenheit,) an instrument which should serve in this art, as in that of the refiner, to ascertain and fix the different degrees of candying (*cuisson*) which the confectioner needs in all his preparations; degrees which he denotes by terms derived from the various appearances which the sugar presents in cooling upon a spoon or the skimmer; namely, candying *au perlé*, (at the pearl;) *à la plume*, (at the feather,) &c.—degrees which have no reference to any fixed limits, and which the most skilful workman always finds difficulty in seizing.

"As the refiners have never understood the nature of the action of heat in the concentration, (*cuite*,) they have not been able to

* See Dutrone, Précis sur la Canne, p. 177.

define it. Also, there seems to be no definition of the term *cuire* in any dictionary, except in the *Encyclopédie*, in which we find: *cuire*, a technical term of refiners, the action of petrifying the sugar in sirup by boiling it for a sufficient length of time. The reader may judge of the merits of this definition.

"The knowledge of the refiner is limited to certain terms, which he uses to designate the particular state in which he finds the sirup he wishes to concentrate, (*cuire.**) As soon as the saccharine solution becomes of the consistence of sirup, he plunges into it a skimmer, and, after taking it out and exposing it to the air, turning it several times upon itself, he holds it steady; if the sirup which is attached to it flows off in separate drops, which fall slowly, he designates this state by the expression *faire la goutte*, to *make the drop.*

"When the concentration commences, if the sirup which covers the skimmer forms a sheet in falling, he designates this state by the expression *faire la toile*, to *make the sheet.*

"Such are the first degrees of the concentration: the others, more advanced, are taken from the signs which the sirup gives when subjected to the *proof by the finger.* This proof consists in taking with the end of the thumb, from a ladle or stirrer which has been plunged into the sirup, a small portion thereof, with which the index or middle finger is then brought in contact, in order to see whether it has acquired sufficient consistence to adhere to the finger, and to be drawn out into a thread when the thumb and finger are separated; in which case it is said to *faire le fil*, *make the thread.* When the sirup is still more concentrated, and the thread thus formed sustains itself well, the thumb is moved towards the base of the little finger, the index being held fixed above; if the thread breaks, they then say that *le fil se rompt*, the *thread breaks.* The other terms are derived from the manner in which the thread is formed and breaks, and the various shapes it assumes in shrinking after it is broken.

"It is in the recollection of these terms, and of some others of like kind, and not less important, that the science of the refiner chiefly consists.

"There are other relative terms—such as *cuite forte*, (strong concentration;) *cuite faible*, (weak concentration;) *bonne cuite*, (good concentration;) but since, in the operation of the *cuite*, there is no fixed or determined point, these expressions refer only to the design of the refiner with regard to the sirup he operates upon, relatively to the quality of the sugar, to the vessel in which he places it to crystalize, and to the state in which he wishes to obtain it; objects which he seeks to attain, but misses more or less, from ignorance or accident."

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* There is, I believe, no English word of the same signification as this French technical term *cuire*, which might be translated *to cook;* but I prefer to use the word *concentrate*, as more correct.

14. Since the time of Dutrone, the beet sugar industry has been established in France, and some new methods of determining the degrees of concentration have been practised there. The terms in use among French sugar refiners are also now fixed by the temperatures corresponding to the degrees of concentration designated by them, as well as by the relative composition of the sirup. The terms themselves are derived, some from the *proof by the touch*, performed as described by Dutrone, and from the forms assumed by the thread between the thumb and finger; and others from the *preuve au soufflé*, described below.

The following table furnishes not only exact definitions of the states of concentration denoted by the technical terms of the French refiners, but also the composition of sirups evaporated to the different corresponding temperatures, as indicated by the degrees of the centigrade thermometer. I have added to the original table, which I extract from the treatise on chemistry of M. Dumas,* only a column adapting it to the scale of Fahrenheit, generally used in this country:

| Temperature. | | Composition. | | Denomination. |
|---|---|---|---|---|
| Centigrade | Fahrenheit | Sugar. | Water. | |
| 133° | 271°.4 | 100 | | |
| 132.50 | 270.5 | 100 | ..... | Cassé sur le doigt. |
| 128.50 | 263.3 | 100 | 10.92 | Grande cassé. |
| 122.10 | 251.8 | 100 | ..... | Petit cassé. |
| 115 | 239 | 100 | 16.29 | |
| 112.50 | 234.5 | | | |
| 120 | 248 | 100 | ..... | Grande soufflé. |
| 119 | 246.2 | 100 | ..... | Soufflé ordinaire. |
| 112 | 233.6 | 100 | 18.84 | Crochet fort. |
| 110.50 | 231 | 100 | 25.05 | Crochet ordinaire. |
| 108 | 226 | 100 | 28.52 | Filet léger. |
| 106 | 223 | 100 | 36.00 | Crochet faible. |
| 105 | 221 | 100 | 41.63 | |
| 104.50 | 220.1 | 100 | 47.26 | |
| 104.25 | 219.6 | 100 | 53.26 | |
| 103 | 217.4 | 100 | 91.11 | |
| 102 | 215.6 | 100 | 88.96 | |
| 101.75 | 215.1 | 100 | 106.81 | |
| 101 | 213.8 | 100 | 124.66 | |

The *preuve au soufflé*, *proof by blowing*, is performed† by dipping a skimmer into the sirup; it is moved to avoid the scum, and slightly shaken in removing it to spread the sirup uniformly over the surface of the instrument; the handle is held horizontally, so that the *disc* is inclined at an angle of about 45°, and the workmen then blow strongly against it. The sirup is well concentrated if at each hole of the skimmer a spherical bubble is formed of at

* See Dumas Traité de Chim. Appliq aux Arts, vol. 6, page 266.
† See Dictionnaire de l'Industrie, p. 407.

least half an inch in diameter. The less the sirup is concentrated, the fewer and smaller will the bubbles be. The vapor arising from the evaporating pan hinders the formation of bubbles, and the diameter of each of the holes in the skimmer should not be more than the eighth of an inch."

15. Another table, also taken from the same valuable chemical work, gives the per cent. of water and of sugar contained in sirup concentrated to the degree corresponding to each technical term.

| Sugar. | Water. | Proof. |
|---|---|---|
| 95.75 | 4.25 | Grand cassé. |
| 92.67 | 7.33 | Petit cassé. |
| 91 | 9 | Grand soufflé. |
| 89 | 11 | Petit soufflé. |
| 88 | 12 | Crochet léger. |
| 87 | 13 | Crochet fort. |

16. The proofs *by the touch* and *by blowing*, *preuve au filet* and *preuve au soufflé*, are the most delicate, convenient and certain, and therefore chiefly employed; but there are other proofs used by French refiners, which are subsidiary to them. Of these, the *preuve à la dent*, proof by the teeth, is performed by trying the sirup between the teeth. "If it offers sufficient resistence without breaking readily, it is nearly concentrated. This proof requires long practice, and cannot be easily described." And the *preuve à l'eau* or *preuve au boulé*, (proof by water or by a ball,) is tried by "putting about half an ounce of the sirup into a vessel of cold water; it is then taken into the hand, and if it can be rolled into a ball without dissolving entirely, or sticking between the fingers, it is sufficiently evaporated. By stretching this mass between the two hands, and placing it between the eye and the light, the smallest portions of foreign matter can easily be seen—such as boneblack, the deposite in the boilers, &c."*

17. Having thus described the methods followed by those who employ open pans to prepare saccharine solutions for crystallization, or, in the technical language of the workmen, to convert the sirup into *strike*, I proceed next to the discussion of the comparative operation of concentration in vacuo.

We have seen that the water cannot be driven entirely from the sugar by heat, without destroying the sugar itself, at the elevated temperature to which it has to be subjected; and that as the temperature rises, the portion of water of solution retained in combination, though it grows less and less, is still sufficient to dissolve

* See Dictionnaire de l'Industrie, p. 108.

all the sugar, in consequence of the increase of affinity due to the heat. But as it cools, the water will abandon the portion which the heat caused it to dissolve; and when it attains the ordinary temperature of the atmosphere, it will be combined with only about twice its own weight of sugar. The sugar abandoned will be crystalline, and will constitute the first and principal product of the manufacture, while the remaining sugar combined with the water will form the *mother-water*, *sirup*, or *molasses*, from which, by subsequent concentration, second products are obtained. The higher the degree of concentration, the less will therefore be the quantity of *mother-water*, or molasses, and the greater the yield of sugar. But to this, as we have already stated, there is a practical limit prescribed by the condition that the consistence or fluidity should be such as to permit the crystallization to take place readily, and the mother-liquor to drain freely.

A very different set of phenomena occur when we evaporate saccharine solutions in vacuo. The temperature of the sirup in this case rarely exceeds 175° Fahrenheit, and therefore much of the water of the sirup which evaporates deposites the sugar it was united with in a solid crystalline form within the vacuum pan.

18. At the temperature of 60° Fahrenheit, a saturated solution of sugar and water is composed of two parts of sugar and one of water; and at 212° Fahrenheit, by reason of the increase of affinity due to the change of temperature, water becomes saturated only when it is united with five times it own weight of sugar. Hence, if we attempt to evaporate a sirup which is saturated at the temperature of 60 Fahr., and by means of heat, so regulated that it shall attain, but never exceed, the degree of 212° Fahr., one-half of the water will have to be converted into vapor before the sirup will constitute a saturated solution at the more elevated temperature it has acquired. But, as soon as the proportion of water is thus reduced, at 212°, from one-third, to one-sixth of the sirup it forms, any further evaporation will cause the sugar to separate in a solid crystalline state, the affinity or solvent power of the water being saturated. And if the operation be continued, sugar will be deposited in the pan, until the consistence of the mixed mass of crystals and sirup becomes too thick either to transmit the heat readily from particle to particle, or to be easily removed from the pan, if it be necessary to draw it off by means of a cock.

Such would be the result of evaporation at 212° Fahr., whether performed in close or open vessels. But if we employ a vacuum pan, then, by virtue of the fact that the temperature is greatly reduced, in consequence of the rapid absorption of latent heat, the mother-liquor, or unevaporated portion of the sirup, will be composed of a more dilute solution of sugar. The solubility of sugar in water at the temperature of 175° Fahr., has not, to my knowledge, been determined accurately and by experiment; but in the absence of such exact knowledge, we may assume, with sufficient probability for our purposes, that at 175° water dissolves four times its own weight of sugar. This cannot be far from the truth; for,

as above mentioned, the solubility of sugar increases with great rapidity at elevated temperatures, but changes between 60° and and 212° Fahrenheit, from two to five times the weight of the water contained. Hence, at 175° Fahr., sirup will evaporate in vacuo, until it is composed of about one part of water and four parts of sugar, and then becomes perfectly saturated. Any further concentration serves but to cause the sugar to separate in crystals. And this deposition of solid sugar may be carried on until the mixture attains a consistence so thick that, if not removed, the mass would solidify in the pan.

So rapid is the evaporation, however, if the vacuum be well maintained, that the contents of the pan do not attain the temperature of 175° Fahr., until their consistence becomes such as to require removal; for, by reason of the diminished pressure, vapor forms at much lower temperatures in sufficient quantity to prevent the sirup becoming heated to 175°, until this evaporation is somewhat checked by the mechanical resistance of the viscid mass or magma which it produces.

19. The following table, taken from Ure's Dictionary, shows the corresponding boiling points and barometric pressures for sirup evaporated in Howard's vacuum pan:

| Temperature, Fahrenheit. | Pressure. | Temperature, Fahrenheit. | Pressure. |
|---|---|---|---|
| ° | Inches. | ° | Inches. |
| 120 | 0.86 | 150 | 2.05 |
| 125 | 1.01 | 155 | 2.36 |
| 130 | 1.17 | 160 | 2.72 |
| 135 | 1.36 | 165 | 3.10 |
| 140 | 1.57 | 170 | 3.52 |
| 145 | 1.80 | 175 | 4.00 |

20. The temperature to which the sirup is evaporated by refiners is usually from 160° to 170°, and it varies with the purity of the solution and nature of the article to be obtained. The semifluid mass of sugar and sirup, called usually *the skippings*, is drawn off from the vacuum pan into a large double-bottomed kettle called *a cooler*, and there heated by steam to 180° or 200° Fahrenheit, from which it is then dipped out and poured into the moulds. By this increased temperature the water of the sirup is enabled to dissolve an additional quantity of sugar, which subsequently solidifies in the moulds, binding the detached crystals together into a compact loaf, and rendering the grain larger and more beautiful, by virtue of the property which large crystals have to grow at the expense of smaller ones.

In the manufacture of vacuum pan sugar, whether from the cane juice or in refining, it is considered highly desirable to obtain a

large crystalline grain. This may, in a measure, be done by heating the cooler as above described, but more effectually by evaporating the sirup in successive portions, so that the crystals obtained from one portion may constitute *nuclei* for the formation of larger crystals in another. By availing himself of the principles of crystallization, the sugar boiler may, indeed, vary the grain of his products almost at his pleasure; large, solid, and perfect crystals being formed by the influence of *nuclei*, fluidity of the mother-liquor, and gentle changes of temperature and density; while rapid evaporation, mechanical agitation, and diffused action, in the absence of centres of cohesion presented by nuclei, tend to produce a confused and finely divided grain.

It may here be observed that the effect of heating in a *cooler* may be accomplished in the vacuum pan itself. For this purpose it is only necessary to destroy the vacuum by admitting the air, and to allow the steam still to act within the double bottom. In this manner, also, the fluidity of the skipping may be increased, and evaporation may consequently be pusbed to a degree which would otherwise be attended with consolidation within the vacuum pan.

The preceding accounts of the indications which present themselves in the evaporation of sirups is applicable to those only which are neutral or pure. Such as are either acid or alkaline behave quite differently. Acid sirups concentrate readily, but become very dark colored towards the close of the operation. *The proof by blowing* takes place in such sirups before *the proof by the touch;* the grain of the sugar obtained is destitute of strength and much discolored, and the green sirup (that which drains spontaneously from the sugar) will not admit of being twice worked. Acidity may be owing either to insufficient defecation, to fermentation by allowing dilute sirup to stand for some time, or to the use of sulphuric acid for neutralizing an excess of temper lime. Whatever may be the cause, the remedy is to employ lime to neutralize the acid, and afterwards to clarify or filter through boneblack.

Alkaline sirups concentrate to the striking point with difficulty. Sometimes they will not froth up in boiling: the sirup itself is thrown up; and if fat be thrown upon the surface it is converted into an insoluble yellow soap, which floats, but exerts no tranquilizing influence. If bubbles form, they appear greasy and come off slowly, and often pass entirely across the surface without bursting. Soon all bubbles cease to form, the action subsides, and, by elevating the temperature, the sirup will be burnt before it will again boil. Alkalinity of sirups is generally owing to an excess of lime in defecation. When this accident has occurred, it is with difficulty remedied. Filtration through boneblack is the only process that has yet been employed with perfect success; it answers well unless the excess of lime be very great. Sulphuric acid has been used extensively in France; but it must be used with great caution, and the object sought must not be *to neutralize more than a portion of the lime*, for the slightest excess of acid which may occur by reason of the salts contained in the juice will do great injury to the

grain and color of the sugar. Hence, test paper should give an alkaline reaction with the sirup, even after the addition of the acid.

21. Carbonic acid gas passed through the alkaline sirup in divided streams, removes all excess of lime effectually, and without the slightest injury to the sugar. For this purpose a simple apparatus is necessary, composed of a vessel in which the gas is generated, by pouring acid on powdered limestone, marble, or chalk, and from which it is conducted by tubes, and permitted to escape into the sirup through numerous small orifices.

The general principles of crystalization, and the methods for ascertaining the degrees of evaporation for sirups, being set forth in the preceding articles, I now proceed to the discussion of the practice both of refiners and manufacturers.

22. By the refiners who employ the vacuum pan, the skippings are heated in the cooler, as described above, and then poured, by means of copper basins or buckets, similar in form to that of plate II., fig. 8, into conical moulds. These moulds are made either of earthenware or of sheet iron, protected from rust by a thick coat of paint. At the time of *filling*, as this operation is technically called, the skippings should be well stirred in the cooler, in order to mix the mass thoroughly, and render it uniform. The moulds, after being filled, are usually allowed to remain quietly until the next day, when they are removed to another room, heated artificially to about 80° Fahrenheit, that the sirup may drain more readily. The bung, which closed the orifice of each mould, having been withdrawn, an awl is used to perforate and break up any solid crust which may have formed at the bottom, and the mould is then placed upon an earthen pot, into which the syrup drips. Sometimes inclined troughs, which lead to a common cistern, are substituted for *dripping pots*, but generally the latter are preferred.

After the sirup has drained somewhat thoroughly from the loaf, which usually requires two or three days, the surface of the sugar is scraped and levelled by means of a circular instrument, known as a *bottoming trowel*, and a quantity of sirup, made of pure white sugar, is then poured upon the loaf. This sirup, or *liquor*, as it is called, sinks down into the porous mass and displaces the colored mother-liquor adhering to the crystals. The operation known as that of *liquoring*, is repeated successively as often as the refiner may think desirable, after which, the loaves are removed from the moulds and placed in the stove to dry.

23. By some of the refiners of Europe, the skippings, instead of being poured into moulds, are transferred to pneumatic troughs, or *tigers*, as they are sometimes called, which are rectangular vessels, about six feet long, four feet broad, and two feet in depth, divided by a false bottom, made of wire gauze or metallic plates, pierced with numerous holes. Upon this false bottom the skippings are

spread in a thin layer, and the sirup is caused to drain thoroughly and rapidly, by means of a vacuum formed between the bottoms. These pneumatic troughs have been used, also, in the English colonies for the manufacture of sugar from cane juice. The sugar obtained with them is said to be much superior to that drained in the ordinary way. In Cuba, I saw these *tigers* in the refinery of Mr. Adams, near Mantanzas, who removes the sugar from them while still very moist, and forms it into loaves by stamping it in brass moulds, after which it is dried in an oven. The loaf sugar he thus makes is far more beautiful and compact than any other which I have seen manufactured from pulvurlent sugar in a similar way. To loaves thus mechanically made, the name of *stamp loaves* is given, and the French have applied the term *sucre tapé*. The method is followed in France, principally at Marseilles, and in the United States by the refiners of New Orleans.

Pneumatic pans have also been employed, in connexion with Rillieux's apparatus, by Messrs. Packwood and Benjamin, in Louisiana; these gentlemen, at first, found difficuly with them, but they have, of late, used them with perfect ease and success. (*)

If pneumatic troughs be used for draining, the granulation should be performed in the coolers or the vacuum pan; for, if crystallization takes place to any extent in the pneumatic pan, the consequence would be that the perforated bottom would become obstructed.

24. When, in refining sugar, the sirup has been concentrated to the striking point by evaporation in open vessels to 235° Fahrenheit, and then transferred to the cooler, the subsequent treatment varies according to the nature of the product to be obtained. If a large and solid grain be desired, then the cooler is about two-thirds filled with successive skippings; and the whole mass being well mixed, to render it uniform, is allowed to remain quiet until crystals begin to form on the surface and upon the sides of the vessel; it is then stirred gently with a wooden instrument, resembling, and called, an *oar*, and in such a manner as to diffuse the crystals as nuclei through the liquid; after this stirring, the sirup being again permitted to be quiet, a second crop of crystals is formed, which also are similarly distributed by stirring. This operation is repeated the third time, and the mass is then removed into the moulds. This method answers equally well for the inferior grades of *lump*, *bastard*, etc.

25. In France, a variety of refined sugar much in request, especially for coffee, and of a very white and spongy texture, is manufactured by a method of granulation the reverse, almost, of that just described. The cooler is filled to one-fourth of its capacity with sirup, concentrated to the usual degree, which is then violently agitated, so as to cause evaporation and rapid cooling; the

* See Appendix, note I.

crystalization is thereby accelerated, but rendered confused and finely divided. When transferred to the moulds, the operation of *hauling*, as it is technically termed, is performed but once; the minute crystals are separated by sirup of greater density, in consequence of lower temperature; and they form, when drained, a mass of little solidity or brilliancy of grain, but which is more readily dissolved, and therefore preferred for some purposes. If we attempt to treat sirups of inferior quality in this manner, they form *stopped loaves*, or a pasty mass, from which the molasses would not drain freely.

The operation of *hauling*, above mentioned, is simply that of stirring the sugar in the moulds, in such a manner as to detach the crystals which form and adhere to the interior of the vessel, and mix them with the crystalizing mass, so that they act as nuclei, as well as give uniformity to the loaf. This operation is usually repeated two or three times; after which, the sugar remains undisturbed for several hours, and is then allowed to drain.

It is evident, from the above, that the results obtained by refiners are in strict accordance with the principles of crystallization which I have enumerated; the whole secret of their art in granulation being to allow repose, when a firm, large, and brilliant crystal is desired, and to agitate violently, and cool rapidly, to obtain a very fine grain of opaque whiteness, and without the lustre due to reflection of light from crystalline planes; and in each instance to produce uniformity of texture, by distributing as nuclei the crystals which form more readily upon the sides and bottom of the containing vessel; which operation, when a large grain is desired, is performed gently, to avoid mechanical injury to the crystals.

26. The method employed by the refiners for the manufacture of rock candy illustrates beautifully the effect of gentle and undisturbed crystallization, and the influence of nuclei. For this purpose the sirup is concentrated highly to 245° Fahrenheit, known to the French refiners as *petit soufflé*, and at which bubbles commence to form when the skimmer is moistened with sirup and blown upon, as above described. As soon as the concentrated sugar is *skipped off* into the cooler, it is immediately transferred into the crystallizing vessels; these are usually copper pans, in the form of truncated cones, pierced with eight or ten small holes, so that threads may be stretched from side to side; upon which threads the crystals chiefly attach themselves. To prevent any escape of sirup from the holes in which the threads are fastened, paper is pasted over the outside.

The crystallizing vessels being previously prepared, they are filled as rapidly as possible and placed in the stove. The temperature is kept as constantly as possible at about 100° Fahrenheit, and every possible care is taken to avoid any disturbance by shaking, by currents of air, etc. After six or eight days the pans are removed from the stove, and the sirup drained off from the crystallized sugar, by perforating the crust and inverting the vessel. The solid contents are taken from the copper pan by placing it ex-

ternally and for a moment in boiling water; they are then thoroughly dried by warm air, and in this condition pass into commerce.

27. The manufacturers of beet sugar in France employ two methods of crystallization: one analogous to that for making rock candy, just described, and known as the method of *slow* or *regular crystallization*; and the other similar to that of the refiners, spoken of, in contradistinction, as the method of *confused crystallization*, or *crystallization in mass*, but oftener as the method *by concentration*, (*la cuite*,) or *the quick method*. The preliminary operations differ almost entirely for the two methods, with the exception of expressing the juice. Indeed, the method of slow crystallization owes its use, in the manufacture of beet sugar, entirely to the employment of sulphuric acid for defecation; a false step which involves modifications in all the subsequent operations. Although sulphuric acid separates the albumen and some other substances, it also acts upon the sugar, and, unless supersaturated with lime, remains in small quantities in the sirup; which, therefore, cannot be concentrated in the ordinary method to 235° Fahrenheit without becoming very dark colored. Hence the necessity of a different method of crystallizing such acidulated sirups, as a remedy for the evils incident to the use of the acid, but which, however meritorious in itself, yet is designed only to correct erroneous work, and therefore cannot be considered an improvement in the general progress of the sugar industry. Since the use of coarse-grained bone-black and of improved methods of evaporation has become general in France, the manufacturers of beet sugar have abandoned this faulty sulphuric acid or *slow crystallization* process, and have adopted the practice of the cane sugar makers and refiners, or the *quick method*.

When sulphuric acid is used, and the beet sugar maker therefore follows the method of slow crystallization, he boils only to 32° Beaumé. This limit has been found by experience the best; for, if it be exceeded, the juice becomes too deeply colored, and the crystallization will progress too rapidly; and if, on the other hand, the sirup be made dilute, then it will not crystallize for a long time, and is apt to become fermented. When the sirup has been boiled to 32° Beaumé, and becomes cooled down to 120° to 130°, it is put into vessels called crystallizers, of the dimensions of 22 inches in length, 14 inches in breadth, and 4 inches in depth, which are made of tin plate. These vessels are then arranged in a stove, or heated chamber, the temperature of which is kept regularly at 100° to 110° Fahrenheit; in this stove the sirup evaporates gradually, and the crystalline crust which constantly forms upon the surface is daily broken, that it may not prevent the access of the air to the fluid portion and impede evaporation. The operation is finished at the end of six weeks, and the crystallizers are then removed from the stove, and inverted over a cistern to drain off the larger part of the molasses. The sugar remaining in mass in the crystallizers is knocked out and crushed by passing it seve-

ral times between two cylinders or rollers. It then constitutes a pasty pulp; to expel the molasses from which, it is put into sacks and subjected for twenty-four hours to the action of a powerful hydraulic press; in this state it is thrown into commerce. The sirup, or mother-liquor, which drains or is expressed from the sugar, is placed in crystallizers, and set in the stove to evaporate and produce a second crop of crystals, though of an inferior quality; the molasses from which, being similarly treated, yields a third and still inferior product.

The manufacturers of beet sugar who defecate with lime and animal charcoal only, and who, therefore, employ the method *à la cuite*, or concentrate the sirups to 235° Fahrenheit, transfer this concentrated sirup to the filling room, (*l'empli*,) which is artificially heated to 80° Fahrenheit, and there allow it to stand in coolers until crystals begin to form. This will take place for good and well concentrated sirup at 225° Fahrenheit, for second products at 200° Fahrenheit, and at 170° to 160° Fahrenheit for third products. It is then filled into conical moulds similar to those for bastard sugar, used by the refiners; the crystals being at the time of filling distributed as uniformly as possible through the mass by stirring in the coolers. The temperature of the room is carefully kept at 80° Fahrenheit; and as soon as the contents of each mould have cooled, the bung is removed to permit the sirup to drain.

If the sirup has not been thoroughly concentrated, it may be violently agitated in the cooler to evaporate it still further, in a manner similar to that used by the manufacturers of clayed sugar from cane juice, or it may be stirred in the moulds by an operation like that practised by the refiners, and called by them *hauling*, or *mouvage*, the object of which is to render crystallization more rapid and general by diffusing *nuclei* through the liquid. In the manufacture of beet sugar, however, it is not desirable, as in refining, to give uniform texture to the loaves, inasmuch as the sugar is crushed before it is sold, and therefore presents a better grain if it be allowed to crystallize without much stirring.

28. The method of crystallization employed by the manufacturers of cane varies with the kind of sugar which is to be made. For *muscovado* sugar the juice is struck from the *battery* or *striking teache* into large coolers or wooden vats, about eight or ten feet long, four or five feet broad, and one foot deep; the chief use of these vats being to correct faults committed in one skipping by mixing it with another of opposite character. Thus, sirup which is highly concentrated becomes mixed with and compensates for that which may be insufficiently evaporated. There are usually a large number of these coolers, and the strike is distributed so that it may form a shallow layer in each. This layer is allowed to granulate before another layer or charge is added; and to give uniformity, as well as to hasten the crystallization, the charges are well stirred together. After remaining in the vat for a day, and while still warm, the sugar is potted, or put into hogsheads, which are covered with boards to retain the heat, and which stand over

the cistern into which the molasses drains. It is very important that the sugar should crystallize in large and perfect grains, and that it should therefore be quietly and carefully done, as well as that the crystals when formed should not be broken; and certainly the method just described must be considered as a very rude and imperfect mode of attaining the desired results.

In making clayed sugar the contents of the battery, when concentrated to the desired degree, 235° Fahr., which is known by the sirup giving the corkscrew curl between the thumb and finger, are transferred as quickly as possible into the cooler, and there immediately subjected for some ten or fifteen minutes to a peculiar agitation or beating. This agitation is done by tossing the sirup rapidly and frequently with a copper ladle attached to a long handle, and in such a manner as to throw the sirup up in a thin sheet—an operation not easily described, and requiring a little skill and strength to perform aright; the design of which is to present a large surface for evaporation to the air, as well as to cause the more rapid crystalization.

The grain of sugar thus treated would, of course, be rendered extremely fine if the crystallization were allowed to proceed far in the cooler; but this is prevented by transferring the sirup, before it granulates much, and while still very hot, into large conical moulds, exactly like those employed by the refiners for bastard sugar. In these moulds the crystallization is quietly completed, the minute grains formed in the cooler acting somewhat as nuclei for the production of a larger and firmer granulation. After the moulds and their contents have attained the temperature of the atmosphere, (which in the West Indies is almost constantly about 80° Fahr.,) the plugs are drawn from the orifices, and a small portion of the molasses drains off. This molasses is called, in Cuba, *miel de descarga*—a name also generally applied there to *muscovado molasses*, and in contradistinction to the term *miel de purga*, or clayed molasses. Without waiting, however, for the *miel de descarga* to drain, and as soon as convenience requires that room be made for the succeeding skippings, the moulds are removed to the purgery—a large building, the floor of which is composed of a sort of grating or lattice work, made of narrow boards, crossing each other at right angles, so as to present numerous square openings, in which the moulds are placed securely. Below this floor inclined troughs are arranged, to catch the molasses which drips from the sugar, and convey it to the cistern.

For the manufacture of *muscovado sugar*, sirup is more highly concentrated (240° to 245° Fahr.) than for that of *clayed sugar*, (235° to 240° Fahr.;) the degree being always, however, determined only by the *proof by the touch*. The temperature which the juice attains when evaporated to 27° Beaumé, and before it is transferred to the battery, I found to be 214° Fahr. It is, therefore, in the battery that injury by overheating chiefly and perhaps almost entirely occurs.

29. The experiments of M. Dutrone, in St. Domingo, seem to

have been directed particularly to the improvement of the processes used for crystallizing and draining both muscovado and clayed sugars. As the method he finally and successfully practised is peculiar, and appears to have features which may hereafter be adopted more generally, and with advantage, by sugar manufacturers, I have extracted the following abridged translation and description of it from Dutrone's work:*

"The purgeries, in the new method, serve both for crystallizing and draining the sugar. These buildings present inside several rows or files of crystallizing vessels, placed over troughs, which empty into several cisterns. The crystallizing vessels should all be of one form and size. A certain number of them are devoted to the crystallization of first products, and the sirup from these flows into a separate cistern. Others are intended for second products, or sugar made from sirup which drips from the first; and similarly, third, fourth, and fifth products have their respective crystallizing vessels and cisterns, in order that they may be kept distinct, and worked separately.

"Experience has proved to me that the quantity of matter which combines the greatest number of advantages in the crystallization of cane sugar is fifteen or sixteen cubic feet; for which reason, the dimensions given to the crystallizing vessels are, five feet in length by three feet in breadth. The bottom is formed of two planes, inclined six inches, (plate IV, fig. 3,) the intersection of which forms a groove in the middle. In this groove there are twelve or fifteen holes, of an inch in diameter, to permit the sirup to flow out. The depth is nine inches at the sides, and fifteen inches at the centre. The vessels should be made of boards one inch thick, and lined with lead. Before lining it, the holes should be bored in the groove, and burnt out with a hot iron from the inside, so as to form a small cavity surrounding the hole; in consequence of which, not a drop of sirup will remain after draining. These holes must be lined with copper or tin, fastened by soldering on the inside, but by small nails externally. Such vessels combine every possible advantage in crystallizing and purging with the requisite strength.

"The crystallizing vessels rest upon strips of wood two inches thick and three inches broad, which are fastened to and supported by upright posts eight or ten inches high, at the distance laterally of ten inches from the middle line. The troughs are of masonry, lined with lead, and incline toward the cisterns. These cisterns are also of masonry, covered with lead, and each of them should be of the capacity of one-half the contents of the crystallizing pans which drain into it."

30. Dutrone's method of manufacture for muscovado sugar is, then, to concentrate only to 87°.5 or 88° Reaumur, (229° or 230° Fahr.;) and having mixed well together two skippings in the

* See Dutrone, Précis sur la Canne, ch. X art. III, page 184.

cooler, to transfer the whole promptly to the crystallizing vessels; the holes having been previously stopped with wooden plugs, upon which a small quantity of concentrated sirup has also been poured, which, by solidifying as it cools, renders them perfectly tight.

"After twenty-four hours, the crystallization being established at the surface, and on the sides and bottom of the vessel, the whole mass, still fluid, must be stirred slightly with a paddle, the sugar which has settled to the bottom being carefully raised to the surface. After this operation, crystallization will progress simultaneously through the whole mass; and if the stirring has been properly performed, it becomes general and uniform from the bottom to the top in five or six hours. After four or five days, the whole mass being cooled, the plugs are drawn; the draining then proceeds rapidly, and is complete after six or eight days. The sugar is slightly moist; but, after a little exposure to the air, it becomes perfectly dry, and is put into hogsheads.

"By concentrating to 88° R., (230° Fahr.,) we obtain one half, and even more, of all the sugar in the juice; and if the defecation and crystallization have been properly performed, this sugar will be of the highest degree of purity and beauty that brown sugar can attain."

For clayed sugar Dutrone recommends that the sirup be concentrated to 90° R., (234½° Fahr.,) and that three or four skippings be well and carefully mixed together in the cooler before filling the conical moulds; after which, the work proceeds in the ordinary manner.

## Section VI.—*On drying.*

1. Under this head I shall treat not merely of the simple drying of sugars which are moistened by only a slight quantity of pure water, but also of those preliminary operations by which the dark colored and deliquescent molasses is removed, so as to purify the sugar, and permit it to be properly dried; the most important of which operations are those of *claying* and *liquoring*.

*On claying*, (Fr. *terrage*.) This process, the office of which is the removal of the dark colored mother liquor, or molasses, from crystallized masses of sugar, is practised by the refiners, as well as by the beet and cane sugar makers. It is, when compared with liquoring, a very rude method, and should be abandoned on account of the great waste which attends it, (25 per cent., more or less.) I shall not, therefore, discuss all the details of this process, but limit myself to a succinct description of it, and an exposition of the facts upon which an intelligent mode of proceeding should be based.

The clay to be employed should be perfectly plastic, and must not contain sulphuret of iron, which may become soluble. It is well mixed into a fine paste with water, which is done either by hand or by a mill turned by a horse or other power, and this paste is then put upon the surface of the sugar, previously levelled in the conical moulds; the water passes from the clay slowly and

gently, occupying the interstices between the grains and dissolving the molasses, and a portion also of the sugar. The saturated solution thus formed displaces mechanically the molasses from the inferior strata; and when it is in turn displaced by the sirup formed by the water with the purified sugar of the upper portion of the mass, the whole loaf becomes free from the molasses.

By the refiners this operation of claying is carried to the extent of removing the molasses entirely, so that the whole loaf becomes white; after which it is stood upon its base to diffuse the sirup through it uniformly, and then placed in a stove to dry.

But by the manufacturers of *clayed sugar* in Cuba, and elsewhere, it is found too wasteful to carry the process of claying so far. When *clayed sugar* is taken from the mould, or *knocked out*, as it is called, the loaf is therefore perfectly white only at its base, and dark brown at the tip; while the intervening portions are gradually more or less white or brown, as they are respectively nearer to the *white* or *brown* end. A mass so constituted may, of course, be divided into an indefinite number of grades of sugar, differing from each other successively by almost imperceptible variations of color and quality.

2. In Cuba, it is customary to make six grades of clayed sugar on an estate; two grades of white, and four of brown. Only five grades are, however, made from one single loaf, in consequence of the white sugar of each loaf being classed as of the first or second quality, by comparing it with standard samples. The Spanish terms or names for these six qualities are: 1st. *Blanco primera*, or *blanco florete*, (Fr. *première*,) prime white. 2d. *Blanco segunda*, (Fr. *seconde*,) second quality white. 3d. *Quebrado florete*, (Fr. *troisième*,) superior brown or yellow. 4th. *Quebrado primera*, (Fr. *belle quatrième*,) prime brown. 5th. *Quebrado segunda*, (Fr. *quatrième ordinaire*,) second quality brown. 6th. *Cucuruche*, (Fr. *tete*,) cockroach, or inferior brown tips. It is, of course, the desire and aim of every sugar maker to manufacture as large a quantity as possible of *florete* sugars; but the quality of the juice, the dose of lime, the regulation of the heat, and the degree of purging, are so many circumstances which modify more or less the result. Hence the qualities of the sugars made on the various soils and estates, as well as at different times, or by different persons, on the same estate, are very distinct, and command higher or lower prices accordingly. Hence, also, in commerce, the six grades of any one estate are compared with those of other estates, and much more nice and numerous classifications of quality are fixed upon. A prominent and experienced merchant of Cuba informs me that he classifies clayed sugars into about fifty varieties, each of which is better adapted than the others to some particular market, and therefore has its own proper fluctuation of demand and supply, and consequent relative price.

3. The above mentioned facts are of importance, especially in relation to any tariff framed upon the basis of specific duties; for

they show how very imperfect and insufficient a mere classification of "white, yellow, and brown clayed sugars" must inevitably be, and also how difficult it is to make proper distinctions which shall depend upon any thing else than the values. The color of sugars is also only one of the specific differences which regulate their relative values, and for clayed sugars it is indeed far less important than the strength and dryness of the grain. Clayed sugars are usually bought by the refiners; and so easily can they extract all coloring matter by the improved method of filtering through animal charcoal, that the color of the sugar has become a secondary matter in comparison with its grain. A very slight difference of price in favor of brown sugars will therefore cause them to be preferred to white.

Under the tariff of 1842 the revenue officers experienced great difficulty in distinguishing between *white* and *brown* clayed sugars, and the difficulty was not even entirely removed by the method that was adopted, of selecting standards and furnishing samples thereof to the surveyors of the different ports, by which they could so regulate their inspections as to produce uniformity of practice. One reason for this difficulty was the fact, that it often requires an experienced judge to decide whether a sugar is to be classed as *blanco segunda*, or *quebrado florete;* between which there is only a shade of difference in color, if any at all; for sometimes a difference of *grain* determines to which class the sugar properly belongs, in which case the sense of touch is relied upon more than the eye; a good grain being recognised by a gritty feeling between the thumb and forefinger, like that produced by particles of sand. Between absolute whiteness and the dark brown of the *cucuruche* there are, and can be, no division lines of color which shall distinguish "*white*" from "*yellow*," or "*yellow*" from "*brown*" clayed sugars; the clayed loaf being continuously and gradually shaded through every intermediate degree of brownness, from its snow-white base to its molasses-dyed tip. All classifications, therefore, based upon color only, are arbitrary and capricious, as well as too easily varied to be adapted to revenue purposes.

After clayed sugar has been *knocked* out, and divided into the different grades of white and brown, which is done by cutting up the loaf with *machetes*, (large knives,) it is dried, first by exposure to the sun, and then upon shelves in a warm apartment, heated artificially to about 120° Fahr., resembling the drying oven of the refiners. In this oven the sugar remains usually from 12 to 36 hours, according to the degree of defecation and of purging, and the greater or less exposure to the sun which may have occurred; after which it is packed in boxes and sold.

The operation of claying is based upon the fact that molasses is more readily dissolved by water than crystallized sugar; and the clay performs the office only of a porous substance, from which the water may escape uniformly and with great slowness. Yet, as it is necessary that a large portion of sugar should dissolve, in order to expel the solution of molasses sufficiently, a heavy and inevitable loss attends the operation. In Cuba the manufacture of clayed

sugar would be abandoned, were it not for the fact that most of it is shipped to Europe, and commands a more ready sale as well as a higher price than muscovado, because it is not subject to the loss by draining, which always occurs with the latter.

4. *On liquoring*, (Fr. *clairçage.*) This operation has for its object the complete removal of the molasses from crystallized sugar without dissolving any portion of the sugar, and it answers the desired end perfectly. It possesses all the advantages, and is free from all the defects, of claying; and it must, therefore, after the vacuum pan of Howard, and the use of boneblack, introduced by M. Derosne, be considered as the third very important step in the progress of the sugar industry of the world. To the fertile invention of Mr. Howard this valuable improvement, I believe, must be ascribed.

5. The following description of, and remarks upon, the operation of *liquoring*, as practised by the refiners and beet sugar makers of France, are taken from a work of M. Payen,* a distinguished sugar manufacturer and chemist.

"Liquoring requires certain precautions, without which its success is very doubtful. Before detailing them, we will indicate the principles upon which this process depends, and which will serve to deduce the rest.

"By *liquoring* is meant the infiltration of a saturated sirup. Incapable of dissolving sugar, this sirup displaces the molasses and dissolves the coloring matter which stains the surfaces of the crystals; it fills the interstices, drips out, and leaves the sugar much less colored.

"The conditions essential to its success are:

"1st. That the liquor be sufficiently charged with crystallizable sugar to dissolve little or none in filtering.

"2d. That the density of the liquor be nearly the same, or very little less than that of the displaced sirup; for, if too dense, it would flow badly; too dilute, it would escape without removing the sirup or molasses adhering to the crystals. To attain this condition, the sugars used for preparing the *liquor* must be more impure in proportion as those to be liquored are so likewise; for saturated sirups are the more dense and viscid when they contain uncrystallizable sugar.

"3d. That the crystallization in the moulds be regular and not too compact; and to this end, that it commence and terminate in the same vessel.

"4th. That the temperature of the room in which the liquoring is performed should not vary much, and be at least 70° Fahrenheit.

"The operation is performed as follows: For the raw sugars of the first jet, the crystallization (entirely performed in the moulds)

* See Cours de Chimie Élémentaire et Industrielle, par M. Payen.

is complete in fifteen or twenty hours. The superficial crystalline crust is then removed from the base of each loaf with a trowel, and the surface is levelled. These surface scrapings (or rather those of a previous day's work) and the sugar infused with sirup have been used for the preparation of a *liquor*, which has been filtered at 28° or 30° Beaumé, boiling, through a filter Dumont, or which has been concentrated to 32° Beaumé, boiling; which corresponds to 36½° at the temperature of 60° Fahrenheit.

"About five pounds of this liquor is poured at one time into each drained mould, containing about 60 pounds of crystallized sugar, if the concentrated sirup put into it weighed from 93 to 100 pounds. This operation is repeated three times, at intervals of 12 hours, and the sugar is then allowed to drain for three or four days. At the end of this time it may be put into casks, and it will be much drier and less alterable than ordinary brown sugar.

"The sugars of the second crystallization are treated similarly. The liquor employed for them should be more dense, 33° to 33½° Beaumé, *boiling*, or 37° to 37½°, *cold*. It is prepared from inferior sugar, and the solution is filtered and concentrated as above. For refined sugars nearly pure sirup must be employed, which, when saturated, should indicate 33°, *cold*, only."

6. More recently the usual practice of beet-sugar manufacturers has been to employ for making the liquor, beet-juice evaporated to 15° or 18° Beaumé, in which they dissolve the tips and crusts of the preceding operations. Experience has shown them that liquoring should be performed in a room heated to 70° or 80° Fahrenheit; and it has become customary, after knocking out the loaves, to divide them in two pieces. The tips are placed in forms over pots to drip, and each half of the loaf is stood upon its base to diffuse the retained moisture uniformly. As soon as they become firm, they are divided into smaller pieces; and, when dry, they are assorted into various qualities, pulverized, and sold.

7. Of the details of the mode of liquoring of the different refiners of the United States, I possess no information which I feel at liberty to publish. The principles which they follow are, in substance, the same as those given by M. Payen in the above translated extract. The temperature of the apartment in which the operation of liquoring is performed should, however, be higher in proportion as the quality of the sugar is low.

The whole art of liquoring consists in the uniform and judicious application of pure sirups for the mechanical *displacement* of molasses. It must be borne in mind, however, that mixture will always take place to some extent, and that the coloring matter and other impurities of molasses are very soluble in saturated solutions of crystallizable sugar. The economical management of the proces, therefore requires that the liquor should be prepared either by decolorizing defecated juice, or solutions of crude materials, and that the rule should be strictly followed never to degrade any refined article, which has once passed through the whole series of operations, by mixing it with molasses. Defecated juice, or impure solutions, must in any event be evaporated with greater or

less injury and loss; to employ these, therefore, as far as possible for displacing impurities, is to avoid the waste of better materials. In so doing, we do not change chemically the composition of a single atom, and the mean result is, therefore, the same; nor do we cause a particle of sugar to retrograde in its progress towards chemical purity. A simple rule may be given and easily remembered: to consider each particle of sugar as advancing through successive operations, which should result in its being obtained in a perfectly refined condition, and never cause it to retrace its progressive steps; while bastard sugar may be regarded as residual crude matter, inferior even to the raw material, and be either refined and treated like any other brown sugar, or sold, as shall be found most profitable, in the markets.

8. Liquoring may be performed in pneumatic pans or *tigers*, but there is some difficulty experienced in the operation in consequence of obstruction if it be urged very rapidly. If, at first, the sirup be allowed to act simply by its own gravity, then the filtration be gently accelerated by a feeble partial vacuum until it shall have drained freely, and finally the air be drawn through the mass to remove the sirup adhering to the crystals, I do not doubt that no difficulty will be experienced with pneumatic pans, especially if the operation be performed at a temperature not less than 80° Fahrenheit.

When I was in Louisiana, Messrs. Benjamin & Packwood had tried unsuccessfully to overcome the above mentioned difficulty of obstruction; they have since succeeded entirely, and their present crop has been manufactured, with Rillieux's apparatus and pneumatic pans, into liquored sugar of perfect quality. A specimen of this sugar, presented to me by Messrs. Merrick & Towne, has been analyzed by me, and found to be *chemically pure*. Its crystalline grain and snowy whiteness are also equal to those of the best double refined sugars of our northern refiners. To Messrs. Benjamin & Packwood must therefore be awarded the merit of having first made directly from a vegetable juice sugar of absolute chemical purity, combined with perfection of crystal and color.* This is indeed a proud triumph in the progress of the sugar industry. In the whole range of the chemical arts I am not aware of another instance in which a perfect result is in like manner obtained immediately.

Sugar made by liquoring dries perfectly, and *remains dry;* whereas brown clayed sugars are slightly deliquescent, and consequently, by absorbing moisture from the air, they become moist, though they may have been carefully and thoroughly dried in the oven. This property of deliquescence is due to the molasses retained, from which liquored sugar is free.

9. The stoves employed for drying by the refiners and the manu-

* See Appendix, notes F and I.

facturers of clayed sugars might perhaps be in many instances highly improved by rendering their operation continuous. This could be done by constructing them horizontally instead of vertically, or in the form of an ordinary room. The heated air might pass in one direction, and the sugar, by a railway, in the opposite direction, so as to present the loaves to drier and warmer air in proportion as they become more deprived of their moisture.

SECTION VII.—*On the working of second products.*

1. My object in this section is chiefly to direct attention to and set forth the importance of second products, and especially of the manufacture of sugar from ordinary molasses.

Under this head I shall not undertake to give any systematic method of extracting sugar from the *mother-liquors* obtained by successive crystallizations, and which shall lead to the greatest economical results; for the particular modes to be followed in each instance will, I hope, be sufficiently evident from the facts given in the preceding chapters. System should, however, pervade all large manufacturing operations; but it must be varied as particular and often unexpected circumstances may require.

When vacuum pans are used for evaporating and boneblack for decolorizating cane juice, the sirup which drains from the sugar is so pure and light colored that a second evaporation will still give *white* sugar.

2. The refiners have long been in the habit of reboiling the sirups which drip from their loaves. They classify their products successively into *double-refined*, *single loaf*, *lump*, *bastard*, and *molasses*, and the sirups from articles of higher grade yield the sugars of inferior quality.

3. By the beet sugar makers, also, the sirups or *mother-liquors* are successively evaporated; and the inferior sugars thus obtained constitute an important item in the economy of this branch of the sugar industry. The sirup which drains from the first crystallization yields sugar of the second quality, the residual sirup from which, in turn, furnishes third products; and so on sometimes even to a forth and fifth crystallization, if the sirup will bear it. This successive boiling ceases when the sirup marks 44° Beaumé, for then crystallization will no longer take place.

The sirups which drain of themselves from the crystallized sugar are called *green sirops*, (*sirops verts*,) and those which are displaced by claying or liquoring are called *runnings*, or *drippings*, (*sirops couverts.*)

The runnings from first and second products are usually mixed and concentrated with the green sirup of the first products, to obtain the second products; and the green sirup from the second products furnishes alone the third products, which generally are not liquored, and are very inferior. Usually, it is the sirup which

drains from these third products which constitutes the *molasses* of the beet sugar manufacture.

The use to which this molasses is applied is chiefly that of distillation into alcohol; for which purpose the molasses is diluted to one-tenth of its original strength. The mixture is then treated with a small quantity of sulphuric acid, if necessary, to neutralize any alkaline salts, and placed in large vats to ferment, 2 to 3 per cent. of yeast being employed to excite fermentation. The change is complete in three days, and the liquor obtained by the first distillation is of the strength of 19°. By a second distillation it is then rectified to 38°. In this manner beet molasses yields about 30 per cent. by weight of alcohol, of 0.93 strength. The residue from the distillation is dried and burnt, to extract from it the potash which is contained in such molasses, usually in the proportion of about 10 per cent. The disagreeable taste derived from the pulp of the beet prevents this molasses from being employed for domestic purposes.

4. In Louisiana, the molasses of the cane has until lately been usually considered as an article from which no sugar of good quality can be readily extracted; in accordance with the accepted notion that it consists rather of some mucilaginous substance formed by the destructive action of heat, than that it is simply a saturated, though an impure, solution of sugar and water, inasmuch as it is the mother-liquor from which the sugar has crystallized.

Recently, however, more correct views have been adopted, and on some of the plantations the molasses has been evaporated with a yield of 40 per cent. of sugar of fair quality; a practice which should become general, and which should serve to dispel from the minds of the planters the incorrect views of the chemical nature of molasses which they have heretofore entertained.

5. The practice in the West India islands will be interesting to, and is worthy of the attention of, the planters of our country. In Cuba, both from muscovado and clayed sugars, the molasses respectively called *miel de descarga* and *miel de purga* is either sold for exportation or distilled into rum. The quantity of rum manufactured in that island may be considered trifling. It does not constitute a beverage of the white population, who are remarkable for their temperate habits; and the interest of the planter causes him to withhold it, except as a medicine, from his negroes, who are passionately fond it.

6. Formerly, large quantities of the molasses of this island were sent to New England, and there distilled into rum; a great portion of which was used in the African slave trade, and the rest consumed in this country. Since the slave trade has been checked, and the use of distilled spirits has gone out of fashion, this industry has declined. The reduction of the drawback on domestic distilled spirits, under recent tariffs, has also operated as a further check upon it. The comparatively small quantities yet distilled are

either consumed at home and in Canada, or sent to Africa, as shown by the reports of the commerce and navigation of the United States. Perhaps it is owing in part to the effect of the above mentioned circumstances that the more legitimate industry of extracting sugar from molasses by evaporation in vacuo has arisen at the north.

7. In the British West Indies the molasses is generally distilled with the skimmings of the juice, and the rum which they make is celebrated for its flavor. In the French islands it is considered far preferable to extract sugar from the molasses. The additional investment of capital required for distillation is avoided, and the products obtained sell for nearly the same. The planters of those islands appear to have had correct views of the chemical composition of molasses, and to have conducted their operations with consequent intelligence and skill. The competition which they have encountered in France from the beet sugar industry has probably diffused a spirit of enterprise, which has caused them to advance in improvements greatly beyond the Spanish and British islands.

8. The following results, given by the Marquis de Ste. Croix,* will show the advantages of the French practice in comparison with that of distillation, and also furnish a description of the process employed: 220 gallons of molasses sold at 0.6 fr. per gallon, amount to 132 francs, ($24 55.) If this molasses be distilled into rum, and we suppose it to give the maximum yield of gallon for gallon, then it will produce, at 0.9 fr. per gallon, 198 fr., or $36 83, no deductions being made for fuel, labor, or expense of apparatus.

Again, if we convert the molasses into sugar we need no peculiar apparatus, and it demands less labor. The yield of crystallizable sugar will be 33 per cent. of the weight of the molasses employed, and we shall have 44 per cent. of second molasses. Hence 220 gallons yield 330 kilogrammes of sugar (727.32 pounds) and 96 gallons of molasses. This sugar sells for 0.4 fr. per kilogramme. Therefore,

| | | | |
|---|---|---|---|
| 330 kilog., at 0.4 fr. per kilog., give..... | 132.0 fr., | or | $24 55 |
| 96 galls., at 0.6 fr. per gall., give..... | 57.6 fr., | or | 10 71 |
| | 189.6 fr., | or | 35 26 |

By skilful manufacture we may obtain from molasses 37 per cent. of sugar and 40 per cent. of second quality molasses. If the sirup be evaporated with proportional results a third time, we obtain,

* See Fabrication Actuelle du Sucre aux Colonies: Paris, 1843.

| | | | |
|---|---|---|---|
| sugar of second boiling, as above..... | 132 fr., | or | $24 55 |
| 145 kilog. of third sugar, at 0 4 fr. per kilog. | 58 fr., | or | 10 79 |
| 40 galls. of molasses, at 0.6 fr. per gall.... | 24 fr., | or | 4 46 |
| | 214 fr., | or | 39 80 |

Hence it appears that the profits of evaporating sirups a third time are scarcely sufficient to compensate for the increased consumption of time and fuel; and that the profits of distillation so slightly exceed those obtained by a single evaporation of the molasses, that they do not justify the additional cost of machinery and labor.

9. The molasses is evaporated in the French islands either in the ordinary trains, or in a distinct train appropriated to this purpose. The fault is often committed of diluting it with water, but the more intelligent planters mix it with half its own volume of juice, to render it sufficiently liquid for filtering. This mixture indicates about 29° Beaumé when the cane juice marks 10°. It is then defecated with lime, and sometimes with a small quantity of fine boneblack, according to the usual method. If this defecated liquor be then filtered through Taylor's filters, it yields a better sugar than is obtained from cane juice alone which has not been similarly clarified and filtered. And when the defecated solution is filtered first through *Taylor's filters*, and then through the *Dumont*, or *coarse boneblack filter*, it gives as perfect a result as could be desired.

10. Dutrone seems to have been led by his investigations to correct ideas with reference to the chemical composition and the value of molasses. The method he recommends of crystallizing at a low degree of concentration furnishes, of course, larger quantities of sirups or molasses; and these sirups are evaporated again and again, so as to yield third and fourth products. To the successive evaporation of the sirup the only limit is that prescribed by the effect of the soluble impurities which become concentrated in the mother-liquor by the repeated crystallizations of sugar.

11. The planters who manufacture clayed sugar have, heretofore, paid no attention to the separation of the molasses which flows from the loaves, when first placed in the purging house, and during the first stages of the operation of claying, from the sirups which escape towards the close of the process, and which then consist of little else than a solution of sugar in water. The whole flow together into one common cistern, through troughs usually ill adapted for the conveyance of such viscid substances. Fermentation takes place to a very considerable extent in the troughs, and progresses still further in the cistern. It is to this fermented mass that the name of *clayed molasses* is applied. In the French islands it is sometimes evaporated, but in the Spanish, the *miel de purga*, as it is called, is sold for exportation, and commands a lower price

than *muscovado molasses*, to which it is greatly inferior, by reason of the acetous fermentation it has undergone.

A more sensible and advantageous system might be adopted by the clayed sugar manufacturers, if they would copy after the practice of the refiners and beet sugar makers of France, with reference to the extraction of sugar from their inferior sirups, and who studiously avoid mixing *the green sirups* which drain at first from *the second runnings*, and *drippings*, as they are technically called.

Similar care should be taken, by planters who may follow the practice of *liquoring* sugars, to avoid mixing sirups of finer quality with those of lower grade; and each should adopt a systematic method for working these sirups analagous to that of the refiners.

SECTION VIII.—*On the use and treatment of animal charcoal.*

1. Charcoal has long been known to possess the property of absorbing certain gases with great energy, and it has, consequently, been used as a disinfecting agent. This power it possesses in a remarkable degree, but which varies for different gases; thus, for instance, recently ignited wood charcoal absorbs—

| | | | |
|---|---|---|---|
| 90 | times its own | volume of | ammonia; |
| 85 | do | do | hydrochloric acid; |
| 55 | do | do | sulphuretted hydrogen; |
| 35 | do | do | carbonic acid; |
| 9 | do | do | oxygen. |

The gases are, therefore, not only absorbed, but condensed with great force. It would require a pressure of ninety atmospheres, or 1,350 lbs. to the square inch, to compress ammonia into the space it occupies when thus condensed in the pores of charcoal. This absorbing power of charcoal is mechanical, and is attended with no chemical action, for the gases may be expelled unchanged by heat alone.

2. Equally remarkable, though even more obscure in its theory, is the property which charcoal possesses of absorbing the coloring matters of vegetable substances, first observed by Lowitz, of St. Petersburgh, and since carefully studied by MM. Payen and Bussy. This property is not confined to any one kind of charcoal, and varies in intensity with the porosity, or state of mechanical division. Substances which melt before carbonization, furnish a charcoal of great brilliancy of lustre, and entirely destitute of decolorizing power. Vegetable charcoal has its efficacy greatly increased by ignition with some soluble salt, which is afterwards washed out thoroughly. The coke, or charcoal of bituminous schist, is eminently decolorizing; but the charcoal which seems to be the most powerful, is that obtained from animal substances, and especially when calcined with various soluble salts.

3. The following table of the results obtained by M. Bussy, fur-

nishes accurate information of the comparative decolorizing powers of the different kinds of charcoal.

| Kind of charcoal of the weight of 1 gramme, or 15.433 grains. | Discolors a solution containing 1 per cent. of indigo per litre. | Discolors a sirup composed of 1 part of brown sugar and 20 parts of water per litre. | Relative decolorisation of indigo water. | Relative decolorisation of sirup. |
|---|---|---|---|---|
| Blood burnt with carbonate of potash..... | 1.6 | 0.18 | 50.0 | 20.0 |
| Blood burnt with chalk..... | 0.57 | 0.10 | 18.0 | 11.0 |
| Blood burnt with phosphate of lime..... | 0.38 | 0.09 | 12.0 | 10.0 |
| Glue burnt with carbonate of potash..... | 1.15 | 0.14 | 36.0 | 15.5 |
| White of egg burnt with same substance.. | 1.08 | 0.14 | 34.0 | 15.5 |
| Gluten burnt with same substance ..... | 0.34 | 0.08 | 10.6 | 8.8 |
| Charcoal from the acetate of potash ..... | 0.18 | 0.04 | 5.6 | 4.4 |
| Charcoal from the carbonate of soda ..... | 0.38 | 0.08 | 12.0 | 8.8 |
| Lampblack not burnt..... | 0.128 | 0.03 | 4.0 | 3.3 |
| Lampblack burnt with carbonate of potash | 0.55 | 0.09 | 15.2 | 10.6 |
| Boneblack after the extraction of the earth of the bone by acid and burning with potash..... | 1.45 | 0.18 | 45.0 | 20.0 |
| Boneblack treated with acid..... | 0.06 | 0.015 | 1.87 | 1.6 |
| Oil burnt with phosphate of lime..... | 0.064 | 0.017 | 2.0 | 1.9 |
| Boneblack from a sal-ammoniac factory.... | 0.032 | 0.009 | 1.0 | 1.0 |

4. The decolorizing power of animal charcoal was made the subject of a prize essay by the Pharmaceutical Society of Paris; and, to the researches of M. Bussy, the results of which are given in the above table, the first prize was awarded. The society also awarded, at the same time, a second prize to M. Payen, whose investigations established the following facts, which I give in his own language.

1st.* The decolorizing power of different kinds of charcoal depends chiefly upon the state of division in which they occur.

2. In the different sorts of charcoal, the carbon alone acts on the coloring matters, which it separates by uniting with them.

3. In the application of animal charcoal to the refining of sugar, it acts likewise upon the vegetable extractive matters and promotes crystalization in a remarkable manner.

4. In conformity with the above principles, the decolorizing action of the different varieties of charcoal may be so modified that the most violent may become the most active.

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* See Payen, Cours de Chim. Elém. et Indus.

5. The distinction which some have sought to establish between animal and vegetable charcoals is incorrect, and we should substitute for it that of charcoals of dull and brilliant lustre.

6. The various earthy substances usually mixed with charcoal, and with animal charcoal especially, exert only an influence of position relatively to that of the carbon; they serve as auxiliaries by separating the particles of carbon, and thus render it more free to act upon the coloring matter.

7. Animal charcoal, besides the decolorizing power, has the property of removing lime in solution either in water or in sirup.

8. The ammonia in boneblack is sometimes useful in the treatment of sirups.

9. Neither vegetable charcoal nor charcoals generally possess the property of removing lime either from water or sirups.

10. By means of an instrument called the *decolorimeter* it is easy to measure exactly the decolorizing power of all kinds of charcoal.

5. The decolorimeter of M. Payen will be readily understood by reference to plate IV, fig. 4. To measure with it the decolorizing power of any specimen of charcoal a proof liquor must first be prepared, and for which purpose a solution of either indigo or molasses is made; molasses should be preferred for this purpose by sugar manufacturers, since the decolorizing power varies somewhat for different kinds of coloring matter, as is shown by the table of Bussy. Equal portions of this proof liquor are then to be subjected to the action of equal weights of the several kinds of charcoal to be compared. The proportion used in each experiment by M. Payen was one decilitre (6 ounces) of the proof solution, and two grammes (30 grains nearly) of the charcoal. The two are well shaken together and then filtered; the filtered liquor is poured into the vertical tube (C D) of the instrument; then by drawing out the horizontal sliding tube (B B) a stratum for observation is obtained of any desired length. The observer looks through the sliding tube towards the light, and adjusts the length of the stratum of liquid through which he looks, until he obtains the same intensity of color as that presented by a portion of the proof-liquor enclosed between two discs of glass (P) attached to the instrument: he then reads off the divisions of the graduated scale upon the horizontal sliding tube. The first whole division marks a thickness exactly equal to that of the liquid between the two discs: No. 2 indicates a double thickness; No. 3 a triple, and so on. If, for any specimen submitted to examination, the corresponding division of the scale observed were No. 2, it is evident that the charcoal would have extracted exactly one-half of the coloring matter. The subdivisions of the graduated scale permit the fractional parts of the decolorizing power to be determined.

6. The great efficacy of M. Dumont's method of employing coarse grained instead of fine boneblack, has led some into erroneous views upon the subject. Its superiority is to be attributed

solely to the manner of its use, the sirups being brought more intimately and thoroughly into contact with the carbon, by the process of filtration, than is practicable with fine boneblack in the method usually employed to cause it to act upon them. Unless stired constantly, it settles by its weight to the bottom. If it were practicable to filter sirups rapidly through fine boneblack, the effect produced would be greater than that attained by using coarse boneblack.

Mechanical subdivision by multiplying the points of contact greatly increases the decolorizing power. For saccharine solutions, the density of which does not exceed 12° or 15° Beaumé, a mixture of one-third of fine with two-thirds of coarse boneblack will allow filtration to be performed readily, and will act far more energetically than coarse boneblack alone. In refining sugar, when fine boneblack alone is used, it is requisite to employ ten per cent. for clarification; but when the clarified liquid is afterwards to be subjected to filtration through Dumont filters, from three to five per cent. only of fine boneblack is usually employed in clarification, and nine or ten per cent. of coarse boneblack is subsequently used in filtration. Fine boneblack which has been once used retains the impurities it has absorbed so tenaciously that it can only be used as a refuse article for manure, while coarse grained boneblack may be revived and employed successively and indefinitely any number of times.

7. When boneblack has been badly prepared by overheating and exposure to the air, so as to burn off a portion of the carbon united with the earthy substances, its energy will be greatly impaired. This fault will be readily detected by the eye. When, however, it has been sufficiently calcined, it will retain a portion of animal oil and empyreumatic matter, which will impart a peculiar disagreeable flavor to the sirup, which cannot be removed. Boneblack of this sort is not easily moistened, and may be recognized in preparing the filters, and sometimes even by the taste or smell. When calcined a second time these defects are corrected, and it may thus be rendered fit for use.

8. A slight portion of carbonate of ammonia, produced by the calcination of the animal matter in the bones, and retained by boneblack, and a portion of carbonic acid, absorbed perhaps from the air, are probably the agents which accomplish the separation of lime from solution in water or in sirup. In performing this office, the carbonate of ammonia is decomposed; hence it becomes expedient, when boneblack is used to remove any excess of lime which may have been employed in defecation as well as for decolorization, to add always a fresh portion, not only for the purpose of restoring that which may have been separated in sifting, in the form of fine boneblack, but also to retain always a portion of the carbonate of ammonia of which it has been deprived; and in places where carbonate of ammonia may readily and cheaply be obtained, (as may generally be done at establishments for gas light-

ing, in which bituminious coal is employed,) it would perhaps be found advantageous to wash a portion of the coarse boneblack with a weak solution of carbonate of ammonia previous to its use in filtration. Such a practice would be attended with no injurious consequences, and would doubtless enable the manufacturers of cane and beet sugar to correct promptly and readily the effects of any excess of lime used in defecation.

9. There are two methods in use for preparing boneblack. The first, which was employed by MM. Payen and Pluvinet, and which is also still used, consists in calcination in large iron retorts, similar to those used for the manufacture of gas for lighting cities. The bones, previously stripped of adhering flesh and fatty matter, are placed in a retort, and then kept at a cherry red heat for 36 hours; after which, they are taken out and ground. In the other method the bones are put into iron pots, of such form that one pot can be made to enter for a short distance within another, their mouths being together; so that two pots, when joined, form a single closed vessel. Into these pots, thus united, about 50 pounds of bones are usually put, and a furnace, resembling somewhat a potter's kiln, is then charged with a number of these pots and their contents, which are piled one above another in the furnace: after remaining at a red heat in the oven until calcination is complete, and until the furnace has cooled down, the pots are taken out and their contents emptied and ground.

10. The mills employed for grinding calcined bones are of three kinds: one with vertical rollers, which is objectionable on account of the large waste it produces in fine dust; another, with horizontal stones, resembles the common flour mill; a third, and the best, consists of a pair of steel rollers, with grooved surfaces, which may be set at any desired distance apart, so as to divide the bones into grains of corresponding size. After the bones are ground, they are twice sifted: first, through a sieve, the interstices of which are large, and which is intended to remove any lumps which may have escaped; and then through a fine sieve, to remove the fine powder and retain the grains. These grains vary in size, usually from 0.03 to 0.2 of an inch in diameter. It is desirable, however, that they should be of uniform size, and not exceed .01 inch.

11. The revivification of boneblack is a subject of the first importance to the manufacturers of sugar, as upon it depends the economy of its use. Various methods have been from time to time attempted, but none of them apparently with perfect success. The coloring and other extractive matters absorbed form a coating, which may be removed either by fermentation or calcination. Calcination, when performed in close vessels, is apt to injure the decolorizing power, by fusing the vegetable substances absorbed and converting them into carbon of brilliant lustre and feeble energy. Fermentation, on the other hand, seems to perform its office but imperfectly, and to leave a large proportion of the impurities in the boneblack.

12. M. Derosne has consequently adopted the method of calcination in contact with air; and he has endeavored to render the process continuous by employing a sort of Archimedes screw, surrounded by a furnace, and thus kept at low red heat. The boneblack, after being well washed and dried, is put on at one end, and the helix or screw turning slowly upon an axis slightly inclined, the revolutions cause it to pass through and escape at the other end. A convenient tub, furnished with paddles or arms attached horizontally to a vertical axis, is employed for washing the boneblack. This tub is also supported upon a horizontal axis, upon which it can be turned so as to incline it to any desired extent, and even invert its position, by which arrangement the water may be first poured off, and the boneblack then emptied in mass.

Many of the refiners employ for revivification of boneblack the iron retort of gas manufacturers, which certainly combines great simplicity of construction with convenience of use. Whether or not the difficulties which M. Derosne has sought to obviate by his method of calcination in contact with air can be overcome by the regulation of the heat in such retorts, I have not the requisite information to decide. It is to be regretted that but little has heretofore been generally known of, and that but few investigations have been made upon, this important subject, of which a few of the refiners only seem to possess any considerable knowledge—the fruit, usually, of dearly bought experience.

13 The only method of fermentation which has been extensively tried is that by M. Peyron, which I have already spoken of under the head of filtration, and to which article I therefore refer. This method has the advantages of continuous action, and of not requiring the boneblack to be removed from the filters, and, could it be rendered practicable, it would doubtless constitute an important improvement in the manufacture of sugar.

14. A third process has lately been invented, which consists in the transmission of a current of steam, heated to the temperature of 750°, through the boneblack; of the results of this method, tried in France, I have no means of accurate information.* It is, how-

* From an excellent article in De Bow's Review of January, 1848, written by J. P. Benjamin, esq., I make the following extract:

"Much talent and labor have been expended in devising the best means of economical and effective revivification, but I have heard of none so satisfactory as that by heated steam, which I saw employed on a very large scale at two refineries near Paris. The black is thrown into a heap after being used and allowed to ferment; it is then thrown into a cylinder, and steam heated to 750° F. is driven through it. The steam is heated by being conveyed through pipes placed in a furnace so arranged as to heat them red hot without the actual contact of the fire, which would otherwise soon destroy them, nor is this process at all attended with the danger which might be supposed to result from the great degree of heat imparted to the steam. The action on the boneblack is at once to destroy, by combination all the organic matters absorbed into the pores of the charcoal during its use and the purgation of all impurities. The black when taken from the cylinder is simply sifted, and is found then to be fully equal to new black, and one of the refiners stated that he considered it as constantly improving by this process. This mode of revivification is cheap, simple, and superior to any with which I am acquainted. The proper degree of heat in the tubes is very simply indicated by dropping on them a metallic alloy, which melts at 750° F. When the alloy begins to melt, the boneblack is discharged, and a fresh charge introduced into the cylinder."

ever, spoken of in terms of high commendation by some of the most distinguished French chemists, and particularly by M. Dumas.*

15. No process of revivification can be considered complete which does not remove not only the vegetable extractive matter, but also the lime which is absorbed by the boneblack, at least occasionally. Unless this lime is removed, it accumulates and obstructs the pores of the boneblack, so as greatly to impair its energy.

16 Fermentation in contact with atmospheric air, by the production of acetic acid, decomposes the carbonate of lime, and forms a soluble acetate; but if calcination be employed, it is necessary to wash the boneblack, from time to time, with dilute acid. For this purpose sulphuric acid is used by some, and muriatic by others: sulphuric acid, however, is to be preferred, not only for the sake of economy, but also because the sulphate of lime exerts no injurious effect, if it be not, as M. Braconnot thinks, positively beneficial; while the chloride of calcium formed by the muriatic acid possesses deliquescent properties which may be highly detrimental, unless the salt be entirely removed by washing before the boneblack is used for filtration.

17. The chief objection to the use of boneblack in the manufacture of sugar has heretofore been its cost. It is usually manufactured in large cities, from materials gathered at considerable expense; but the fact should be taken into consideration, that, when properly revivified, it may be used repeatedly, and until it is gradually consumed by the losses it sustains each time in consequence of the fine boneblack detached and separated from it in the mechanical operations to which it is subjected. The only expense, therefore, sustained, is that which is necessary, from time to time, to restore the portions thus lost; and with reference to the original investment of capital employed, it may be safely stated that the additional profits of a single crop, resulting not only from the improvement in the quality, but also in the increased quantity of the sugar manufactured, will far more than repay the outlay.

18. This statement is proved by the following comparative results of refining with and without boneblack, given by M. Payen:

| | Old method, by lime. | Method by fine boneblack. | Method by coarse boneblack. |
|---|---|---|---|
| Sugar in loaves and clayed lumps.... | Per cent. 55.276 to 57.86 | Per cent. 61.63 | Per cent. 63.47 |
| Bastard sugar..... | 17.085 to 17.36 | 18.29 | 19.23 |
| Molasses..... | 25.126 to 22.18 | 17.34 | 14.41 |
| Loss, &c..... | 2.513 to 2.60 | 2.74 | 2.89 |

* See Dumas, Trait. de Chim., vol. vii, p. 521.

19. It has been considered a great desideratum to obtain some abundant and cheap substitute for boneblack. The only substance as yet successfully tried is bituminous schist. In France there is at Ménat, in the départément of the Puy de Dome, an extensive geological formation of this rock. It has been thoroughly tried by the manufacturers of beet sugar, who prepare it for use by calcination, in a manner precisely similar to that employed for boneblack. It is composed, according to the analysis of M. Payen, of silica, alumina, carbon, a bituminous oil analogous to petrolium, the sulphuret of iron, sulphate of alumina, and ammonia, and some traces of nitrogenous matter, soluble in boiling water. And after calcination, it forms an intense black mass, which is light, friable, and easily reduced to powder; it is then composed of:

| | |
|---|---|
| Silica | 50 to 60. |
| Carbon | 20 to 25. |
| Alumina | 10 to 15. |
| Iron and sulphur | 2 to 3. |
| Sulphate of lime, Sulphate of alumina, | traces. |

20. When bituminous schist is used in fine powder, it communicates a brown tinge to the sirup. But the principal objection to its use in the manufacture of cane or beet sugar, as a substitute for boneblack, is, that it does not possess the property of removing lime, as well as coloring matters. As a decolorizing agent, it is, however, more powerful than boneblack; and it might, therefore, be used with advantage in refining. The power of absorbing lime might be imparted to it by washing it in a solution of carbonate of ammonia, or by mixing it with a portion of boneblack.

21. It is stated* that a mixture of 10 parts of clay, 2 parts of tar, and 50 of fine bituminous coal, well kneaded together, and then calcined, will form a composition, the decolorizing power of which is but little inferior to that of boneblack; and it is evident, from the principles established by MM. Payen and Bussy, that we may readily form an almost indefinite number of artificial decolorizing mixtures. But in attempting to substitute any thing in the place of the boneblack now employed, regard must be had to the mechanical properties requisite for filtration and revivification without considerable loss; as well as to the property of removing lime, even more important and indispensable, perhaps, than that of decolorization. Whatever agent may be employed, filtration will, probably, be found necessary to produce sufficient mechanical contact, and obtain a proper effective result.

*See Berzelius, Trait. de Chim.

## CHAPTER III.

### ON THE DRAWBACK UPON REFINED SUGAR, AND THE IMPORTATION OF MOLASSES AND SIRUPS.

1. *On drawback.*—Upon this subject I have already submitted, on a former occasion, (Sen. Doc. No. 165, 2d sess. 28th Cong.,) a full and accurate report; to which I beg leave, therefore, to refer.

The conclusions I had then reached were, however, open to two objections: first, that they were based upon limited operations, the refining of 25,000,000 pounds of raw sugar; and, secondly, that the results were known to me only by the testimony of interested witnesses.

2. I therefore visited nearly all the large and many of the smaller refineries of the Atlantic cities, in obedience to my instructions, and with the object of ascertaining the average or general yield of refining, both by the modern and by the old process. The plan I pursued, when practicable, was, to examine the books of the establishment, and compute the yield of refining from the amount of raw sugar purchased, and refined sugar sold. These books, designed only for the private use and information of their owners, were submitted to my examination confidentially, but willingly and unhesitatingly; and from knowledge thus acquired and extended, I can testify that thirty per cent. of white sugar and seventy per cent. of brown (the average mixture) yield:

| By the vacuum process: | | By the old process: | |
|---|---|---|---|
| Refined | 55.4 | Refined | 53.6 |
| Bastard | 22.9 | Bastard | 19.6 |
| Molasses | 17.4 | Molasses | 24.5 |
| Dirt and waste | 4.3 | Dirt and waste | 2.3 |
| | 100.0 | | 100.0 |

Of the 53.6 per cent. of refined sugar obtained by the old process, 40 will be *loaf*, and 13.6 will be *lump sugar*.

Under the present tariff it is not improbable that a larger relative proportion of white clayed sugar may be used; if so, the yield of refined sugar will increase, at the expense chiefly of the molasses. I should suppose that it might even become, by the vacuum process:

| | | |
|---|---|---|
| Refined | 55.0 to | 60.0 |
| Bastard | 23.0 to | 23.0 |
| Molasses | 17.5 to | 12.5 |
| Dirt and waste | 4.5 to | 4.5 |
| | 100.0 | 100.0 |

3. *On molasses.*—Much has of late been said of fraudulent importations of sugar into the United States under the name of molasses. The whole subject has been thoroughly and carefully investigated by the Treasury Department, and the results are given in Sen. Doc. No. 12, 28th Cong., 2d sess., and in Sen. Doc. No. 467, 1st sess. 29th Congress; to which I therefor refer.

From the analyses of sugars and molasses given in the latter of the above mentioned Senate documents, and also in chapter 4, of this report, it will appear that West India or Louisiana molasses contains, on an average, 52 per cent. of crystallizable sugar; that the *maximum* amount of such sugar contained in the best and strongest sirups of the refiners, or in *sirop de batterie* is 60 per cent.; and that considerable quantities of sugar have been manufactured from molasses by some of the refiners of New York, Philadelphia, and Baltimore. In Senate Doc. No. 12, 28th Congress, 2d session, it is stated also that 35 per cent. of good sugar is the yield obtained by these refiners, a fact which is confirmed by information I have myself received.

4. This branch of manufacture owes its origin entirely to the operation of our revenue laws. The relative duties being disproportionate, it has resulted that sugar could be readily and profitably extracted from molasses. Ignorance, however, led to suspicions that a business apparently so forced must be based upon fraud; and these suspicions were sustained by the incorrect statements and calculations of persons whose interests are opposed to the importation and consumption of foreign sugar, and who therefore were, probably, too easily convinced of what they would fain imagine to be true. The fact that molasses contains 52 per cent. of crystallizable sugar, and *sirop de batterie* but 60 per cent., should put the question entirely at rest, especially under any tariff which levies a low duty on the former and a prohibitory duty on the latter. (See chapter 4 for further information.)

5. One of the principal objects proposed by Congress in these researches was understood to be the discovery, if practicable, of some chemical mode of distinguishing genuine *molasses* from *sirop de batterie*, and which might also be used by the custom-house officers with certainty and ease. After a thorough investigation of the whole subject, I confidently assert that no such discovery is possible, for the simple reason that *sirop de batterie* of inferior quality often differs from superior molasses (*sirop d'egout*) in no sensible respect, whether we rely upon chemical tests, or such as are furnished by our senses. The *sirop de batterie* occasionally imported in small quantities is a choice article, carefully selected for the purpose; no one can mistake it for ordinary molasses, or be deceived by it; but when the juice from which it was made has been limed in excess, or the heat has been improperly managed, *sirop de batterie* presents all the peculiarities by which molasses (*sirop d'egout*) is usually recognised, and even the most experienced sugar planters might mistake the one for the other.

The inspectors of the revenue and grocers are familiar only with molasses; they rarely see *sirop de batterie*, know little of it, and usually believe it to resemble somewhat in taste and color a solution of sugar and water: they are confident they could detect it easily; but as they never see it of inferior quality, they would almost invariably be deceived by it. I am sure I could introduce it under the name of molasses, without much trouble, under any tariff act which may levy discriminating duties upon sirups and molasses. It will be, therefore, found difficult to distinguish molasses from *sirop de batterie*, nor can chemical analysis remove or in any degree lessen the difficulty.

Chemically, cane juice must be regarded as a solution of sugar in water, combined with impurities only to a very slight degree. By defecation some of these impurities are separated; the rest still remain in solution. They vary also in quantity with the soil, the weather, the climate, etc. *Sirop de batterie* is this defecated and and impure aqueous solution of sugar, concentrated by evaporation to 35° or 40° Beaumé, or to saturation; molasses is the same saturated solution as mother liquor, indicating from 35° to 40° Beaumé, after concentration to 235° Fahrenheit, or 42° Beaumé, and the crystallization of a portion of the sugar in cooling. As the quantity of the impurities varies continually, there is of course no fixed relative chemical composition; and, though molasses will always contain a somewhat larger proportion of foreign matter than the particular sirup from which it was made, it may be much purer than the *sirop de batterie* on an adjoining plantation; or even on the same estate after a change of weather. The distinction, therefore, is one of attending circumstances, and not of composition; and the question to be answered is one of fact,—whether or not the solution has ever been allowed, in part, to crystallize? If so, it must be called *molasses*, otherwise *sirop de batterie*. Direct testimony is, therefore, the only evidence which can be adduced to determine the matter. A decided flavor of caramel furnishes *presumptive* evidence that concentration has been pushed high enough for crystallization; but this will often prove deceptive, for battery sirup may also be flavored with caramel, if any portion becomes overheated upon the sides or bottom of the pan.

6. It has been erroneously asserted by some that the *miel* of Cuba is *sirop de batterie*, or sirup in some other equally pure state, and that therefore it is imported fraudulently if under the name of *molasses*. I will therefore add, that in that island *sirop de batterie* is always called *melado*. Clayed molasses is known as *miel de purga*, and the molasses which drips from brown sugar in the hogsheads is called *miel de descarga*. The latter is in every respect the same as Louisiana molasses, and is superior to *miel de purga*. The term *miel de descarga* is also applied to the first drippings from the moulds into which the strike is put for making clayed sugar, but this article is trifling in quantity and never exported.

7. The simplest, readiest, and by far the most delicate test for

distinguishing sirups, is the sense of taste, guided by experience; and whenever the taste can detect no appreciable difference, the commercial values will not vary. Hence no difficulty would arise if the duties on sirups and molasses bear the same proportion to their respective values. But discriminating duties may give rise to perplexing questions of facts, and in such cases chemical analyses can afford no assistance.

## CHAPTER IV.

### ANALYSES OF SPECIMENS OF MOLASSES, SUGARS, ETC., RECEIVED FROM THE REVENUE OFFICERS.

The following chapter contains, in tabular form, the results of the analyses of all the different specimens of molasses, of sediments taken from casks in which molasses was imported, and of the different varieties of muscavado and clayed sugars, which were collected by the revenue officers of the ports of Boston, New York, Philadelphia, and Baltimore, during the months of August and September, 1845, and sent to me for chemical examination, in compliance with orders issued by the Treasury Department; also, the memorandum of the inspector, the external indications of quality, the data furnished by optical observation, and the resulting per cent. of crystallizable sugar for each specimen; which together constitute a complete description, and will enable the importer to recognise the article which he may have introduced. The numbers of the tables correspond with the numbers prefixed to each descriptive memorandum.

## TABLE I.—*Molasses.*

| No. | Taste. | Color. | Where from. | Where imported. | Specific gravity | Per cent. of cane sugar. |
|---|---|---|---|---|---|---|
| 1 | Acid | Dark | Havana | Boston | 1.342 | 50.78 |
| 2 | Very acid | ..do | ...do | New York | 1.360 | 52.84 |
| 3 | Acid | ..do | ...do | Philadelphia | 1.358 | 53.1 |
| 4 | Slightly acid | Very dark | ...do | ....do | 1.357 | 53.27 |
| 5 | .....do | Dark | ...do | ....do | 1.348 | 57.75 |
| 6 | .....do | ..do | ...do | ...do | 1.350 | 56.80 |
| 7 | Acid | ..do | ...do | New York | 1.348 | 48.84 |
| 8 | Very acid | ..do | St. Jago de Cuba | Philadelphia | ..... | 53.51 |
| 9 | Acid | ..do | .....do | ....do | 1.340 | 59.83 |
| 10 | Slightly acid | ..do | .....do | ....do | 1.334 | 60.49 |
| 11 | Acid | Light | .....do | Boston | 1.350 | 50.33 |
| 12 | Slightly acid | Dark | .....do | ....do | 1.378 | 44.58 |
| 13 | .....do | ..do | Cienfuegos | Philadelphia | ..... | 50.99 |
| 14 | .....do | Brownish red | ....do | Boston | 1.377 | 56.49 |
| 15 | Sweet | Light | ....do | ....do | 1.376 | 49.56 |
| 16 | Vinous | ..do | ....do | ....do | 1.429 | 49.33 |
| 17 | Acid—vinous | ..do | ....do | ....do | 1.367 | 57.34 |
| 18 | Vinous | ..do | ....do | ....do | 1.369 | 56.69 |
| 19 | Slightly acid | ..do | ....do | Philadelphia | ..... | 54.70 |
| 20 | .....do | Dark | ....do | ....do | ..... | 45.54 |
| 21 | Acid | ..do | ....do | ....do | ..... | 50.98 |
| 22 | Slightly acid | ..do | Trinidad | New York | 1.384 | 49.28 |
| 23 | .....do | Light | ....do | ....do | 1.362 | 51.31 |
| 24 | Vinous | Dark | ....do | Philadelphia | 1.361 | 53.26 |
| 25 | Sweet | ..do | ....do | Boston | 1.360 | 48.30 |
| 26 | Acid | Light | ....do | ....do | 1.349 | 47.69 |
| 27 | ..do | Dark | Matanzas | Philadelphia | 1.357 | 54.56 |
| 28 | Slightly acid | ..do | ....do | ....do | 1.354 | 51.24 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 29 | Acid | ..do | Cardenas | New York | 1.357 | 48 |
| 30 | Acid and burnt | ..do | ....do | Boston | 1.363 | 52.47 |
| 31 | Vinous | ..do | Sagua la Grande | ....do | 1.342 | 48 58 |
| 32 | Very acid | Very dark | .....do | ....do | 1.351 | 44.78 |
| 33 | Vinous and bitter | Light | .....do | Baltimore | 1.346 | 55.47 |
| 34 | Vinous | ..do | San Juan de los Remedios | Boston | 1.354 | 54.46 |
| 35 | Acid | Dark | Mariel | ....do | 1.369 | 55.14 |
| 36 | Slightly acid | Light | Nuevitas | New York | 1.363 | 56.19 |
| 37 | | | ....do | ....do | 1.336 | 60.31 |
| 38 | Sweet | Light | ....do | ....do | 1.337 | 59,71 |
| 39 | | | ....do | ....do | 1.368 | 46.81 |
| 40 | Sweet | Light | Porto Rico | ....do | 1.365 | 53.07 |
| 41 | Slightly acid | Dark | ....do | ....do | 1.369 | 51.5 |
| 42 | | | Ponce, P. R. | ....do | 1.377 | 55.60 |
| 43 | Vinous | Light | ....do | Philadelphia | 1.358 | 62.14 |
| 44 | Slightly acid | Dark | ....do | ....do | 1.367 | 58.52 |
| 45 | .....do | ..do | ....do | Baltimore | 1.371 | 60.73 |
| 46 | Vinous | Light | ....do | ....do | 1.376 | 48.84 |
| 47 | Bitter | Red | ....do | New York | 1.354 | 46.55 |
| 48 | | | Mayaguez | ....do | 1.371 | 55.24 |
| 49 | Vinous | Light | ....do | ....do | 1.366 | 54.91 |
| 50 | Sweet | ..do | ....do | ....do | 1.362 | 53.41 |
| 51 | | Dark | ....do | Philadelphia | 1.359 | 50.38 |
| 52 | Slightly acid | Light | ....do | Boston | 1.348 | 57 |
| 53 | .....do | ..do | ....do | Baltimore | 1.370 | 56.20 |
| 54 | Sweet | Dark | ....do | Philadelphia | 1.345 | 49.47 |
| 55 | Very acid | ..do | Guayama | New York | 1.354 | 60.33 |
| 56 | Bitter | Light | ....do | ....do | 1.376 | 60.95 |
| 57 | Slightly acid | Dark | ....do | ....do | 1.361 | 54.30 |
| 58 | Acid | | ....do | ....do | 1.362 | 53.82 |
| 59 | Vinous | Light | Arecibo | Baltimore | 1.376 | 48.93 |
| 60 | Sweet | ..do | Naguabo | New York | 1.367 | 55.89 |
| 61 | Acid | Dark | Surinam | Boston | 1.337 | 50.66 |
| 62 | Slightly acid | Light | St. Croix | New York | 1.376 | 56.24 |
| 63 | Sweet | ..do | ....do | ....do | 1.340 | 51.65 |
| 64 | ..do | ..do | St. Thomas | Boston | 1.378 | 58.54 |
| 65 | Vinous | Dark | ....do | Baltimore | 1.355 | 57.97 |
| 66 | ..do | ..do | St. John's | Boston | 1.357 | 52.49 |
| 67 | ..do | Black | ....do | ....do | 1.353 | 50.17 |
| 68 | Sweet | Light | Xibara | New York | 1.369 | 56.89 |
| 69 | ..do | ..do | Humacoa | ....do | 1.372 | 50.13 |

TABLE I.—*Molasses*—Continued.

| No. | Taste. | Color. | Where from. | Where imported. | Specific gravity. | Per cent. of cane sugar. |
|---|---|---|---|---|---|---|
| 70 | Slightly acid..... | Dark ..... | *Miel de purga* ..... | ..... | 1.361 | 49.50 |
| 71 | .....do..... | Light..... | *Miel de descarga*..... | ..... | 1.340 | 50.68 |
| 72 | .....do..... | Dark ..... | New Orleans plantation..... | ..... | 1.352 | 53.18 |
| 73 | Burnt ..... | ..do..... | Sugar-house, Philadelphia..... | ..... | 1.495 | 40.03 |
| 74 | ..do..... | ..do..... | Sugar-house, New Orleans..... | ..... | 1.400 | 43.53 |
| 75 | Sweet..... | Light..... | *Sirop de batterie* ..... | ..... | 1.337 | 60.57 |
| 76 | ..do..... | Very light..... | Lovering's sirup, Philadelphia..... | ..... | 1.3 | 59.76 |
| 77 | Slightly burnt..... | Red ..... | ....do.....do.....2d quality. | ..... | 1.4 | 44.86 |

## TABLE II.—*Sediments.*

| No. | Molasses taken from— | Consistence. | Per cent. of cane sugar. |
|---|---|---|---|
| 1 | Cienfuegos.....No. 21..... | Pasty..... | 74.34 |
| 2 | ....do..... | Pasty and granular..... | 73.90 |
| 3 | Trinidad.....No. 23..... | Pasty..... | 78.62 |
| 4 | ....do.....No. 24..... | Granular..... | 79.55 |
| 5 | Sagua la Grande...No. 33..... | Pasty and granular..... | 81.58 |
| 6 | Nuevitas.....No. 36..... | Pasty..... | 74.38 |
| 7 | ....do.....No. 38..... | Granular..... | 75.34 |
| 8 | ....do..... | ...do..... | 72.20 |
| 9 | ....do..... | ...do..... | 81.47 |
| 10 | ....do..... | Pasty and granular..... | 78.40 |
| 11 | Porto Rico.....No. 41..... | Granular..... | 68.59 |
| 12 | ....do..... | Pasty and granular..... | 77.87 |
| 13 | Ponce.....No. 42..... | ...do.....do..... | 74.19 |
| 14 | Mayaguez.....No. 49..... | Granular..... | 78.54 |
| 15 | ....do.....do..... | Pasty..... | 70.80 |
| 16 | Guayama.....No. 58..... | ...do..... | 76.16 |
| 17 | Naguabo.....No. 60..... | Pasty and granular..... | 76.67 |
| 18 | St. Croix...../No. 62..... | Granular..... | 76.58 |
| 19 | ....do.....No. 63..... | Pasty..... | 74.17 |
| 20 | Xibara.....No. 68..... | Pasty and granular..... | 73.40 |
| 21 | Humacoa.....No. 69..... | ...do.....do..... | 67.90 |
| 22 | ..... | Granular..... | 73.97 |
| 23 | ..... | ...do..... | 80.29 |
| 24 | ..... | ...do..... | 80.63 |
| 25 | Mayaguez.....No. 50..... | Pasty and granular..... | 72.83 |
| 26 | ..... | Granular..... | 93 |
| 27 | ..... | Pasty and granular..... | 72.31 |
| 28 | ..... | Granular..... | 74.28 |
| 29 | ..... | ...do..... | 77.23 |
| 30 | ..... | Pasty..... | 75.28 |

## TABLE III.—*White clayed sugars.*

| No. | Color. | Grain. | Where from. | Where imported. | Per cent. of cane sugar. | Remarks. |
|---|---|---|---|---|---|---|
| 1 | White..... | Strong and fine..... | Havana ..... | Philadelphia..... | 99.5 | Dry. |
| 2 | ..do..... | .....do..... | St. Jago de Cuba... | Boston..... ..... | 99 | Dry. |
| 3 | ..do..... | .....do..... | Trinidad..... | ..do. ..... | 95.32 | Dry. |
| 4 | Nearly white..... | .....do..... | Matanzas ..... | Philadelphia..... | 96.58 | Dry. |
| 5 | ..do....do..... | .....do..... | Nuevitas..... | New York..... | 97.55 | Dry. |
| 6 | White ..... | .....do..... | Manzanilla..... | Boston..... | 96.68 | Dry and crystalline. |
| 7 | Nearly white..... | .....do..... | Pernambuco..... | Philadelphia ..... | 100 (?) | Lumps interspersed. |

## TABLE IV.—*Quebrado floretes.*

| No | Color. | Grain. | Where from. | Where imported. | Per cent. of cane sugar. | Remarks. |
|---|---|---|---|---|---|---|
| 8 | Nearly white ..... | Strong ..... | Havana..... | New York..... | 98.58 | Lumps interspersed. |
| 9 | .....do..... | Strong and fine..... | St. Jago de Cuba... | Philadelphia ..... | 97.64 | |
| 10 | .....do..... | .....do..... | Manzanilla ..... | Boston ..... | 98.29 | Crystalline. |
| 11 | .....do..... | .....do..... | Cienfuegos ..... | ..do ..... | 96.94 | do. |
| 12 | .....do..... | .....do..... | Pernambuco..... | ..do..... | 98.08 | Lumps interspersed. |
| 13 | .....do..... | .....do..... | .....do..... | ..do. ..... | 97 | |
| 14 | .....do..... | .....do..... | .....do..... | ..do..... | 96.74 | |

## TABLE V.—*Quebrado 1a.*

| No. | Color. | Grain. | Where from. | Where imported. | Per cent. of cane sugar. | Remarks. |
|---|---|---|---|---|---|---|
| 15 | Nearly white..... | Strong and fine.... | Havana..... | New York..... | 96.89 | |
| 16 | .....do..... | ..do.....do..... | St. Jago de Cuba... | ...do..... | 99.56 | |
| 17 | .....do..... | ..do.....do..... | ....do.....do..... | ...do..... | 97.40 | |
| 18 | .....do..... | ..do.....do..... | ....do.....do..... | Boston..... | 99 | |
| 19 | .....do..... | ..do.....do..... | ....do.....do..... | ...do..... | 97.26 | Lumps interspersed. |
| 20 | .....do..... | ..do.....do..... | Trinidad..... | Philadelphia..... | 98.87 | do. |
| 21 | .....do..... | ..do.....do..... | ....do..... | Boston..... | 98.14 | |
| 22 | Gray-white..... | ..do.....do..... | Nuevitas..... | New York..... | 95.31 | |
| 23 | .....do..... | Mealy..... | Pernambuco..... | Boston..... | 93 | Slightly moist. |
| 24 | .....do..... | ..do..... | ....do..... | ...do..... | 94 | do. |

## TABLE VI.—*Quebrado 2a.*

| No. | Color. | Grain. | Where from. | Where imported. | Per cent. of cane sugar. | Remarks. |
|---|---|---|---|---|---|---|
| 25 | Light brown..... | Fine..... | Havana..... | Philadelphia..... | 95.42 | |
| 26 | Light ..... | Good ..... | ...do..... | New York..... | 96.10 | Lumps interspersed. |
| 27 | ..... | Fine and gritty ..... | St. Jago de Caba ... | Philadelphia..... | 99 (?) | Aroma strong. |
| 28 | Light brown..... | Strong and fine ..... | ...do.....do..... | ....do..... | 98 (?) | |
| 29 | Yellow-white..... | ..do.....do..... | ...do.....do..... | New York..... | 93.31 | |
| 30 | Dull yellow..... | Tolerable ..... | ...do.....do..... | ....do..... | 88.64 | Slightly moist. |
| 31 | Gray-yellow..... | Good ..... | ...do.....do..... | Boston..... | 95.83 | Dull appearance. |
| 32 | Yellow-white ..... | ..do..... | ...do.....do..... | ....do..... | 95.48 | do. |
| 33 | Yellow-brown ..... | ..do..... | Trinidad ..... | ....do..... | 94.89 | Uncrystalline. |
| 34 | Light..... | ..do..... | ...do..... | ....do..... | 93.94 | |
| 35 | Gray-yellow..... | ..do..... | ...do..... | ....do..... | 92.34 | do. |
| 36 | Brown-white ..... | ..do..... | Matanzas..... | Philadelphia..... | 95.06 | Lumps interspersed. |
| 37 | Nearly white..... | Pasty..... | Mayaguez..... | ....do..... | 91.23 | Moist. |
| 38 | Light yellow ..... | Good ..... | Cienfuegos ..... | Boston..... | 93.64 | Crystalline. |
| 39 | Yellow-white ..... | Excellent..... | Manzanilla ..... | ....do..... | 96.72 | do. |
| 40 | Gray-white..... | Tolerable ..... | Bahia..... .... | Philadelphia..... | 95.08 | Moist. |

## TABLE VII.—*Quebrado 3a.*

| No. | Color. | Grain. | Where from. | Where imported. | Per cent. of cane sugar. | Remarks. |
|---|---|---|---|---|---|---|
| 41 | Yellow | Good | Havana | New York | 87.91 | Lumps interspersed. |
| 42 | Brown-yellow | ..do | St. Jago de Cuba | Boston | 91.62 | Uncrystalline. |
| 43 | Light | Fine | Trinidad | Philadelphia | 93.38 | |
| 44 | Brown-yellow | Strong | ...do | ....do | 89.85 | |
| 45 | .....do | ..do | ...do | ....do | 89.37 | |
| 46 | .....do | Tolerable | ...do | ....do | 87.47 | Slightly moist. |
| 47 | .....do | Gritty | ...do | ....do | 91.11 | Lumps of dark color. |
| 48 | .....do | Good | ...do | Boston | 92.16 | Dry. |
| 49 | Red-brown | ..do | ...do | ....do | 91.81 | Uncrystalline. |
| 50 | Deep yellow | Tolerable | Nuevitas | New York | 88,89 | Slightly moist. |
| 51 | Yellow | Good | ...do | ....do | 91.69 | Dry. |
| 52 | ..do | Pasty | ...do | ....do | 84 | Uncrystalline. |
| 53 | Brown | Hard | Manilla | ....do | 91.66 | D'rk lumps intersp'd. |

## TABLE VIII.—*Muscovado sugars.*

| No. | Color. | Grain. | Where from. | Where imported. | Per cent. of cane sugar. | Remarks. |
|---|---|---|---|---|---|---|
| 54 | Deep yellow | Pasty | Havana | New York | 85.35 | Moist. |
| 55 | ..... | Fine and soft | St. Jago de Cuba | Philadelphia | 94.37 | do. |
| 56 | Dark brown | Soft and weak | ...do...do | ....do | 92.18 | do. |
| 57 | Brown yellow | Rather hard | ...do...do | ....do | 88.23 | Lumps interspersed. |
| 58 | Yellow-white | Pasty | ...do...do | New York | 88.23 | do do. |
| 59 | .....do | Tolerable | ...do...do | ....do | 89.79 | Moist. |
| 60 | Deep yellow | Inferior | ...do...do | ....do | 88.30 | Dull appearance. |
| 61 | .....do | ..do | ...do...do | ....do | 95.26 | do do. |
| 62 | Yellow | ..do | ...do...do | ....do | 87.79 | do do. |
| 63 | Dark yellow | Good and fine | ...do...do | Boston | 92.98 | Rather dry. |
| 64 | Light yellow | Tolerable | ...do...do | ....do | 89.06 | Bright and crystalline. |
| 65 | Brown-yellow | Pasty | ...do...do | ....do | 88.47 | Very moist. |
| 66 | Yellow | Strong | Trinidad | Philadelphia | 88.59 | |
| 67 | Dark brown | Inferior | ...do | Boston | 90 | Dull appearance. |
| 68 | Light yellow | Good | Nuevitas | New York | 94.9 | |
| 69 | .....do | Tolerable | St. Croix | ....do | 92.75 | Moist. |
| 70 | .....do | Good | ...do | ....do | 93.22 | |
| 71 | .....do | ..do | ...do | ....do | 92.72 | |
| 72 | Dull yellow | Tolerable | ...do | ....do | 93.33 | |
| 73 | Light yellow | Good | ...do | ....do | 95.14 | Bright and crystalline. |
| 74 | .....do | ..do | ...do | ....do | 96.20 | do do. |
| 75 | Dull yellow | Pasty | ...do | ....do | 91.95 | |
| 76 | Light yellow | Tolerable | ...do | ....do | 96.15 | |
| 77 | .....do | Inferior | ...do | ....do | 95.40 | Dull appearance. |
| 78 | .....do | Good | ...do | ....do | 93.28 | Bright and crystalline. |
| 79 | .....do | ..do | ...do | ....do | 93.94 | do do. |
| 80 | .....do | Inferior | ...do | ....do | 92.14 | Dull and uncrystalline. |
| 81 | .....do | Very good | ...do | ....do | 94.41 | Bright and crystalline. |
| 82 | .....do | ....do | ...do | ....do | 96.30 | do do. |
| 83 | .....do | Inferior | ...do | ....do | 91.24 | |
| 84 | .....do | Good | ...do | ....do | 92.38 | |
| 85 | .....do | ..do | ...do | ....do | 92.65 | Bright and crystalline. |
| 86 | .....do | ..do | ...do | ....do | 94.36 | do do. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 87 | .....do..... | ..do..... | ...do..... | ....do..... | 92.83 | do do. |
| 88 | .....do..... | ..do..... | ...do..... | ....do..... | 95.82 | do do. |
| 89 | .....do..... | ..... | Porto-Rico..... | Philadelphia..... | 92.79 | Moist. |
| 90 | Yellow..... | Good ..... | ...do..... | ....do..... | 88.27 | Lumps interspersed. |
| 91 | ..do..... | ..do..... | ...do..... | ....do..... | 89.33 | Moist. |
| 92 | Light yellow ..... | ..do..... | ...do..... | ....do..... | 92.84 | do. |
| 93 | Dull yellow..... | Tolerable ..... | ...do..... | New York..... | 92.69 | |
| 94 | Deep yellow..... | ..do..... | ...do..... | ....do..... | 96.45 | Crystalline. |
| 95 | Gray-yellow ..... | Inferior..... | ...do..... | ....do..... | 89.46 | Dull. |
| 96 | Dull yellow..... | Good ..... | ...do..... | ....do..... | 85.05 | |
| 97 | Light brown..... | Strong..... | Ponce, P. R..... | Philadelphia..... | 93.48 | Moist. |
| 98 | Light yellow . ..... | ..do..... | ...do..... | ....do..... | 95.46 | do. |
| 99 | Brown-yellow..... | ..do..... | ...do..... | ....do..... | 92.43 | Gritty. |
| 100 | .....do..... | ..do..... | ...do..... | ....do..... | 87.27 | |
| 101 | Light brown..... | Good ..... | ...do..... | ....do..... | 90.03 | |
| 102 | Brown-yellow ..... | Tolerable ..... | ...do..... | ....do..... | 88.95 | |
| 103 | Light brown..... | Good ..... | ...do ..... | ....do..... | 90 | Gritty. |
| 104 | Light yellow ..... | ..do..... | ...do..... | New York..... | 91.85 | |
| 105 | .....do..... | ..do..... | ...do..... | ....do..... | 93.70 | Quite dry. |
| 106 | .....do..... | ..do..... | ...do..... | ....do..... | 88.31 | Moist. |
| 107 | .....do..... | Tolerable ..... | ...do..... | ....do..... | 95.37 | |
| 108 | .....do..... | ..do..... | ...do..... | ....do..... | 91.1 | |
| 109 | .....do..... | Inferior..... | ...do..... | ....do..... | 92 | Dull. |
| 110 | .....do..... | Tolerable ..... | ...do..... | ....do..... | 93.18 | do. |
| 111 | Dull yellow ..... | Good ..... | ...do..... | Baltimore ..... | 92.43 | Crystalline. |
| 112 | Yellow..... | ..do..... | ...do..... | ....do..... | 89.19 | do. |
| 113 | Deep yellow..... | ..do..... | ...do..... | ....do..... | 86.54 | Moist. |
| 114 | Light yellow ..... | ..do..... | ...do..... | ....do..... | 86.26 | |
| 115 | Yellow..... | Gritty..... | Mayaguez ..... | Philadelphia..... | 92.85 | |
| 116 | Light yellow ..... | ..do..... | ...do..... | New York..... | 92.15 | |
| 117 | Yellow-white..... | Inferior..... | ...do..... | ....do..... | 91.68 | Moist. |
| 118 | Light yellow ..... | Good ..... | ...do..... | ....do..... | 91.52 | Slightly moist. |
| 119 | .....do..... | Inferior ..... | ...do..... | ....do..... | 94.1 | Dull. |
| 120 | .....do..... | Good ..... | ...do..... | ....do..... | 95.39 | Bright and crystalline. |
| 121 | .....do..... | Tolerable ..... | ...do..... | ....do..... | 94.95 | do do. |
| 122 | Deep yellow..... | ..do..... | ...do..... | ....do..... | 89.66 | Moist. |
| 123 | Light yellow ..... | ..do..... | ...do..... | Boston..... | 93.48 | Bright and crystalline. |
| 124 | .....do..... | ..do..... | ...do..... | ....do..... | 93.36 | do do. |
| 125 | Yellow..... | Good ..... | ...do..... | ....do..... | 88 | do do. |
| 126 | Light yellow ..... | ..do..... | ...do..... | ....do..... | 91.14 | do do. |
| 127 | .....do..... | ..do..... | ...do..... | ....do..... | 90.21 | do do. |

## TABLE VIII.—*Muscovado sugars*—Continued.

| No. | Color. | Grain. | Where from. | Where imported. | Per cent. of cane sugar. | Remarks. |
|---|---|---|---|---|---|---|
| 128 | Light yellow | Good | Mayaguez | Boston | 95.36 | Bright and crystalline. |
| 129 | do | do | do | do | 88.88 | do do. |
| 130 | do | do | do | do | 87.85 | do do. |
| 131 | do | do | do | do | 92.71 | do do. |
| 132 | do | Tolerable | do | do | 93.20 | |
| 133 | do | Good | do | Baltimore | 87.55 | |
| 134 | do | do | do | do | 89.66 | |
| 135 | do | Tolerable | do | do | 91.43 | |
| 136 | do | Good | do | do | 88.27 | Very moist. |
| 137 | do | do | do | do | 92.09 | |
| 138 | do | Very good | do | do | 93.73 | |
| 139 | do | Tolerable | do | New York | 85 | Lumps interspersed. |
| 140 | Deep yellow | Gritty | Guayama | do | 91.64 | |
| 141 | Dull yellow | Pasty | do | do | 88.48 | |
| 142 | Yellow | Good | do | do | 91.92 | Bright appearance. |
| 143 | do | do | do | do | 94.42 | |
| 144 | Light yellow | do | do | do | 90.95 | Dull and crystalline. |
| 145 | do | do | do | do | 92.43 | Bright and crystalline. |
| 146 | Dull yellow | Pasty | do | do | 91.52 | |
| 147 | Deep yellow | Tolerable | do | do | 90.90 | Crystalline. |
| 148 | do | Inferior | do | do | 88.90 | Very moist. |
| 149 | | | Guayanilla | do | 93.12 | |
| 150 | Deep yellow | Good | do | do | 89.17 | Large crystals. |
| 151 | Dull yellow | Tolerable | do | do | 92.90 | |
| 152 | do | do | do | do | 88.71 | Lumps interspersed. |
| 153 | Light yellow | Good | Arecibo | do | 94.74 | Bright and crystalline. |
| 154 | do | Very good | do | Baltimore | 92.69 | do do. |
| 155 | do | do | do | do | 90.49 | do do. |
| 156 | do | do | do | do | 89.21 | do do. |
| 157 | do | do | do | do | 88.83 | do do. |
| 158 | do | do | do | do | 94.98 | Rather dry. |
| 159 | do | Good | do | do | 92.96 | |
| 160 | Dull yellow | do | do | do | 89.75 | do. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 161 | Light yellow | ..do | ...do | ....do | 90.85 | do. |
| 162 | Yellow | ..do | ...do | ....do | 87.94 | |
| 163 | Light yellow | Tolerable | Cienfuegos | Boston | 91 | |
| 164 | Dark brown | Gritty | Laguayra | Philadelphia | 93.44 | Lumps interspersed. |
| 165 | .....do | Tolerable | Para | New York | 84.55 | do do. |
| 166 | Yellow-white | ..do | Naguabo | ....do | 93.61 | |
| 167 | Yellow | Good | Halifax | Boston | 91.18 | |
| 168 | Light yellow | ..do | ...do | ....do | 91.38 | |
| 169 | .....do | Inferior | ...do | ....do | 91.63 | |
| 170 | .....do | Good | ...do | ....do | 91.52 | |
| 171 | Yellow | Tolerable | ...do | ....do | 89.56 | Very moist. |
| 172 | Light yellow | Good | ...do | ....do | 90.87 | |
| 173 | Dark yellow | ..do. | ...do | ....do | 90.13 | Moist. |
| 174 | Light yellow | ..do | ...do | ....do | 94.72 | Bright and crystalline. |
| 175 | Yellow | Tolerable | ...co | ....do | 92.52 | Moist. |
| 176 | Light yellow | Good | ...do | ....do | 92.21 | |
| 177 | .....do | ..do | ...do | ....do | 92.10 | |

## TABLE IX.—*Miscellaneous sugars.*

| No. | Color. | Grain. | Kinds of sugar. | Per cent. of cane sugar. | Remarks. |
|---|---|---|---|---|---|
| 178 | White | Hard and firm | Lovering's crushed loaf, Philadelphia | 99.39 | Brilliant. |
| 179 | ..do | ..do.....do. | Woolsey's crushed loaf, New York | 98.34 | do. |
| 180 | Light yellow-white | Strong and fine | Superior brown of Cuba, (U. S. standard) | 98.30 | Dry clayed. |
| 181 | Dull white | ..do.....do | Inferior white of Cuba.....do | 98.32 | do. |
| 182 | Light yellow | Good | New Orleans prime sugar | 93.69 | Moist. |
| 183 | White | Strong and fine | New Orleans prime white | 97.79 | |
| 184 | Yellow | Good | New Orleans raw sugar | 92.74 | do. |
| 185 | ..do | ..do | New Orleans sugar | 87.91 | |
| 186 | Dark | | Maple sugar | 78.83 | In cakes. |
| 187 | Yellow | Good | Broome's molasses sugar | 86 | |
| 188 | Dark yellow | Gritty | Lovering's bastard | 78.28 | Very moist. |

MOLASSES.

*Molasses from Havana.*

1. Received from the Boston custom-house, marked "Imported into the port of Boston and Charlestown, in the brig Napoleon, from Havana, by Shurtliffe & Warren, September 8, 1845."

A dark colored molasses, of an acid taste; specific gravity = 1.342.

$e = 0.25$; $a = 21°.9$;
$d = 1.073$; $a'' = -5°.7$;
$t = 65°.7$ F.; $n = 0.9$.

Per cent. of cane sugar, 50.78.

2. Received from the New York custom-house, and marked "Cargo 15, lot 23—23 tierces and 20 barrels molasses, imported in brig Susan, from Havana, September 18, 1845, by John B. Lasala & Co. No sediment in this lot."

A very dark colored, thin molasses, having a decidedly acid taste. Specific gravity 1.360, at 67° F.

$e = 0.25$; $a = 22°.3$;
$d = 1.072$; $a'' = -6°.4$;
$t = 54°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 52.84.

3. Received from the Philadelphia custom-house, and marked "Sample of molasses in tierces from Havana, per brig Samuel N. Gott; no mark. Consigned to S. & W. Welsh, Philadelphia. September 8, 1845."

A dark colored molasses, charged with foreign matter, such as sticks, &c. Its specific gravity is 1.358, at 64° F.

$e = 0.25$; $a = 21°.6$;
$d = 1.076$; $a'' = -7°.2$;
$t = 64°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 53.1.

4. Received from the custom-house, Philadelphia, and marked "Sample of molasses per the barque Louisa, from Havana, consigned to John F. Chesson. There was no sediment to be found in the hogsheads, and no distinction mark upon the heading. Philadelphia, August 18, 1845."

A molasses having a very dark color, and a slight acid taste; apparently free from foreign matter. Its specific gravity is 1.357, at 63°.5 F.

$e = 0.25$; $a = 21°.9$;
$d = 1.0792$; $a'' = -7°.1$;
$t = 52.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 53.27.

5. Received from the Philadelphia custom-house, and marked "Sample of molasses in hogsheads, from Havana, per the brig Samuel N. Gott, Gray, master; no mark. Consigned to S. & W. Welsh. Philadelphia, September 18, 1845."

A rather dark colored molasses, having a slight acid taste. Specific gravity = 1.348, at 64° F.

$e = 0.25$; $a = 23°.7$;
$d = 1.0712$; $a'' = -7°.5$;
$t = 51°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 57.75.

6. Received from the Philadelphia custom-house, and marked "Sample of molasses in hogsheads, from Havana, per brig Caroline, Jordan, master. Consigned to S. & W. Welsh; no mark. August 27, 1845."

A rather dark colored, thick molasses, having a slight acid taste. Specific gravity = 1.350, at 66°.8 F.

$e = 0.25$; $a = 22°.9$;
$d = 1.084$; $a'' = -8°.1$;
$t = 51°.4$ F.; $n = 0.9$.

Per cent. of cane sugar, 56.80.

7. Received from the New York custom-house, and marked "Cargo 15, lot 22—243 hogsheads molasses, imported in the brig Susan, from Havana, September 18, 1845, by John B. Lassala & Co. No Sediment in this lot of molasses."

A very dark colored, quite opaque molasses, have an acid taste. Specific gravity 1.348, at the temperature of 65° F.

$e = 0.25$; $a = 20°.1$;
$d = 1.067$; $a'' = -6°.2$;
$t = 52°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 48.84.

*Molasses from St. Jago de Cuba.*

8. Received from Philadelphia custom-house. A thin, dark colored, sweet, and perfectly opaque molasses. No sediment deposited in the bottle.

$e = 0.50$; $a = 51°.4$;
$d = 1.153$; $a'' = -11°.3$;
$t = 18°$ C.; $n = 0.9$.

Per cent. of cane sugar, 53.51.

9. Received from the Philadelphia custom-house, and marked

"Sample of molasses, in hogsheads, from St. Jago de Cuba, per the brig Vulture, Mayo, master; mark, V. Consigned to Burling & Dixon. August 28, 1845."

A thin watery sirup, having a very acid taste and dark color; abundance of foreign matter, such as chips, &c.; a sediment deposited in the bottle. Specific gravity 1.340, at 66°4 F.

$e = 0.25$; $a = 25°$;
$d = 1.072$; $a'' = -7°.4$;
$t = 60°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 59.83.

10. Received from the custom-house, Philadelphia, and marked "Sample of molasses, in hhds., from St. Jago de Cuba, per the brig Vulture, Mayo, master; marked V. Consigned to Burling & Dixon. August 28, 1845."

A thin, dark colored molasses, having a slightly acid taste; specific gravity 1.334, at 65°.6 F.

$e = 0.25$; $a = 25°$;
$d = 1.081$; $a'' = -8°$;
$t = 41°$ F.; $n = 0.9$.

Per cent. of cane sugar, 60.49.

11. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, in the brig John H. Stevens, from St. Jago de Cuba, by John S. Hill, September 30, 1845."

A rather light-colored molasses, of a thin consistency, and having a decidedly acid taste and odor. Its specific gravity is 1.350.

$e = 0.25$; $a = 20°.9$;
$d = 1.070$; $a'' = -6°.3$;
$t = 54°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 50.33.

12. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, in the brig Eliza, from Cuba, by John S. Harris, September 13, 1845."

A rather dark colored molasses, having a slightly acid-vinous taste; specific gravity = 1.378.

$e = 0.25$. $a = 16°.7$;
$d = 1.074$; $a'' = -7°.3$;
$t = 58°$ F.; $n = 0.9$.

Per cent. of cane sugar, 44.58.

*Molasses from Cienfuegos.*

13. Received from the Philadelphia custom-house. A dark obaque molasses, of a very slightly acid taste; slight sediment deposited in the bottle.

$e = 0.50$; $a = 48°.2$;
$d = 1.146$; $a'' = -11°.1$;
$t =$ $n = 0.9$.

Per cent. of cane sugar, 50.99.

14. Received from the Boston custom-house, and marked "Imported into the port of Boston and Charlestown, in the barque Lysander, from Cienfuegos, by Benjamin Burgess & Sons, September 19, 1845."

A deep brownish red molasses, of a slightly acid taste; specific gravity 1.377.

$e = 0.25$; $a = 22°.8$;
$d = 1.075$; $a'' = -7°.8$;
$t = 58°$ F.; $n = 0.9$.

Per cent. of cane sugar, 56.49.

15. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, in the brig Cordelia, from Cienfuegos, by Benjamin Burgess & Sons, September 25, 1845."

A rather light colored molasses, having a perfectly sweet taste; specific gravity is 1.376, at 63°.2 F.

$e = 0.25$; $a = 21°.65$;
$d = 1.064$; $a'' = -5°.1$;
$t = 54°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 49.56.

16. Received from the Boston custom-house, and marked "Imported into the port of Boston and Charlestown, in the brig Cordelia, from Cienfuegos, by Benjamin Burgess & Sons, September 25, 1845."

A rather thick and light colored molasses, having a vinous taste; specific gravity 1.429.

$e = 0.25$; $a = 19°.8$;
$d = 1.066$; $a'' = -5°.3$;
$t = 50°.2$; $n = 0.9$.

Per cent. of cane sugar, 49.33.

17. Received from the custom-house, Boston, and marked "Im-

ported into the port of Boston and Charlestown, in the barque Lysander, from Cienfuegos, by Benjamin Burgess & Sons, September 19, 1845."

A rather light colored molasses, of a thin consistence, and a slightly acid-vinous taste; specific gravity 1.367, at 64°.8 F.

$e = 0.25$; $a = 23°.9$;
$d = 1.074$; $a'' = -7°.2$;
$t = 58°$ F.; $n = 0.9$.

Per cent. of cane sugar, 57.34.

18. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, August 25, 1845, by Benjamin Burgess & Sons, in the brig Eliza Burgess, from Cienfuegos."

A light colored molasses, having a vinous taste; specific gravity 1.369.

$e = 0.25$; $a = 23°.8$;
$d = 1.080$; $a'' = -7°.2$;
$t = 65°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 56.69.

19. Received from Messrs. E. Lincoln & Co., Philadelphia; a brownish red molasses, having a slight acid taste.

$e = 0.50$; $a = 52°.4$;
$d = 1.1716$; $a'' = -12°.5$;
$t =$ ; $n = 0.9$.

Per cent. of cane sugar, 54.70.

20. Received from the Philadelphia custom-house. A dark, tolerably thick molasses, having a slightly acid taste; a sediment deposited in the bottle.

$e = 0.50$; $a = 43°$;
$d = 1.176$; $a'' = -11°.2$;
$t = 19°$ F.; $n = 0.9$.

Per cent. of cane sugar, 45.54.

21. Received from the Philadelphia custom-house. A dark, thick molasses, having a very slightly acid taste and smell; no sediment in the bottle.

$e = 0.50$; $a = 46°.8$;
$d = 1.155$; $a'' = -12°.8$;
$t = 24°$ C.; $n = 0.9$.

Per cent. of cane sugar, 50.98.

*Molasses from Trinidad de Cuba.*

22. Received from the New York custom-house, and marked "Cargo 21, lot 31—233 hhds. 12 tierces molasses, imported in brig Rowena, from Trinidad de Cuba, October 2, 1845, by Chastelain & Ponvert. It will be found that this sample varies in color from lot 30 (No. 23) of the same cargo. No sediment in this."

A dark colored thick molasses, having a slightly acid taste. Specific gravity, 1.384.

$e = 0.25$; $a = 19°$;
$d = 1.0794$; $a'' = -7°.7$;
$t = 52°$ F.; $n = 0.9$.

Per cent. of cane sugar, 49.28.

23. Received from the custom-house, New York, and marked "Cargo 21, lot 30, 233 hhds. 12 tierces molasses, imported in brig Rowena, from Trinidad de Cuba, October 2, 1845, by Chastelain & Ponvert. Sediment No. 3 is from this molasses."

This molasses is of a deep brownish red by transmitted light, and has a slight acid taste. Specific gravity 1.362, at 59° F.

$e = 0.25$; $a = 20°.9$;
$d = 1.066$; $a'' = -6°.7$;
$t = 52°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 51.31.

24. Received from the custom-house, Philadelphia, and marked "Sample of molasses in tierces, from Trinidad, per schooner Fashion: marked S F, and consigned to S. & W. Welsh, Philadelphia. August 25, 1845."

A dark colored molasses, of a rather thin consistency, and having a peculiar vinous taste. Its specific gravity is 1.3615, at 65°.6 F.

$e = 0.25$; $a = 22°.2$;
$d = 1.074$; $a'' = -6°.7$;
$t = 61°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 53.26.

25. Received from the custom-house, Boston, and marked "Imported into the district of Boston and Charlestown, in the barque Franklin, by Benjamin Burgess & Sons, from Trinidad, October 11, 1845."

A dark colored molasses, having a perfectly sweet taste. Specific gravity 1.360, at 52° F.

$e = 0.25$; $a = 20°.1$.
$d = 1.065$; $a'' = -5°.9$;
$t = 55°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 48.30.

26. Received from the Boston custom-house, and marked "Imported into the port of Boston and Charlestown, in the brig Smyrna, from Trinidad de Cuba, by Philo S. Shelton, September 30, 1845."

A tolerably light colored molasses, having a decidedly acid taste. Specific gravity 1.349, at 62°.5 F.

$e = 0.25$; $a = 21°.2$;
$d = 1.349$; $a'' = -4°.7$;
$t = 49°.8$; $n = 0.9$.

Per cent. of cane sugar, 47.69.

*Molasses from Matanzas.*

27. Received from the Philadelphia custom-house, and marked "Sample of molasses in hhds., from Matanzas, per the barque Levant, H. ———, master. Consigned to George R. Ayres. September 2, 1845."

A dark colored molasses, having an acid taste, and containing an abundance of foreign matter. Specific gravity 1.3576, at 65°.3 F.

$e = 0.25$; $a = 22°.2$;
$d = 1.0759$; $a'' = -7°.4$;
$t = 56°$ F.; $n = 0.9$.

Per cent. of cane sugar, 54.56.

28. Received from the Philadelphia custom-house, and marked "Sample of molasses, in hhds., per the barque Levant, from Mantanzas. Consigned to George R. Ayres; no mark. Philadelphia, September 3, 1845."

A dark colored molasses, with a slightly acid taste, and tolerably free from foreign matter. Specific gravity 1.3545, at 64°.6 F.

$e = 0.25$; $a = 21°$;
$d = 1.0714$; $a'' = -6°.7$;
$t = 55°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 51.24.

*Molasses from Cardenas.*

29. Received from the custom-house at New York, and marked "Cargo 23, lot 33—49 casks molasses, imported from Cardenas, October 14, 1845, by John B. Lasala & Co. No sediment in this lot."

A molasses of a rather thin consistence, and dark color, having a decidedly acid taste; specific gravity 1.357.

$e = 0.25$; $a = 20°$;
$d = 1.072$; $a'' = -6°$;
$t = 57°.5$; $n = 0.9$.

Per cent. of cane sugar, 48.

30. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, in the brig Casilda, from Cardenas, Cuba, by C. B. Fessenden, September 4, 1845."

A dark colored molasses, of a rather thick consistence, and a slightly burnt and acid taste; specific gravity 1.363, at 66° F.

$e = 0.25$; $a = 21°.7$;
$d = 1.068$; $a'' = -6°.6$;
$t = 66°.3$ F.; $n = 0.9$.

Per cent. of cane sugar, 52.47.

*Molasses from Sagua la Grande.*

31. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, in the brig Havana, from Sagua la Grande, by Philo S. Shelton, September 2, 1845."

A molasses of a dark color, and thin consistency, with a peculiar vinous taste; specific gravity 1.342, at 65° F.

$e = 0.25$; $a = 20°.1$;
$d = 1.062$; $a'' = -5°.8$;
$t = 62°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 48.58.

32. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, in the brig Havana, from Sagua la Grande, by Daniel Deshon, September 2, 1845."

A very black molasses, having a very sour taste and odor; specific gravity 1.351, at 55°.4 F.

$e = 0.25$; $a = 19°.1$;
$d = 1.063$; $a'' = -5°$;
$t = 59°.3$; $n = 0.9$.

Per cent. of cane sugar, 44.78.

33. Received from the Baltimore custom-house, and marked "Gauged from on board sloop Herald, John Reynolds, Sagua la Grande; consigned to Lambert Gittings; weight per gallon, 11 lbs. 1 oz. August 18, 1845."

A deep brownish red molasses, having a peculiar vinous and bitter taste; specific gravity 1.346, at 67°.5 F.

$e = 0.25$; $a = 22°.3$;
$d = 1.073$; $a'' = -7°.7$;
$t = 70°.4$ F.; $n = 0.9$.

Per cent. of cane sugar, 55.47.

*Molasses from San Juan de los Remedios.*

34. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, by Atkins Freeman, in the schooner Bounty, from San Juan de los Remedios, August 23, 1845."

A rather light colored molasses, having a peculiar vinous taste; specific gravity 1.354, at 55° F.

$e = 0.25$; $a = 22°.5$;
$d = 1.081$; $a'' = -7°.2$;
$t = 56°.4$ F.; $n = 0.9$.

Per cent. of cane sugar, 54.46.

*Molasses from Mariel.*

35. Received from the Boston custom-house, and marked "Imported into the port of Boston and Charlestown, by J. S. Harris, in the brig Rival, from Mariel, Cuba, August 28, 1845."

A very dark colored, rather thick molasses, having a decidedly acid taste; specific gravity 1.369, at 54° F.

$e = 0.25$; $a = 22°.4$;
$d = 1.064$; $a'' = -7°.2$;
$t = 65°.7$ F.; $n = 0.9$.

Per cent. of cane sugar, 55.14.

*Molasses from Nuevitas.*

36. Received from the custom-house, New York, and marked "Cargo 19, lot 27—83 casks molasses, marked B. Imported in brig Demarara, from Nuevitas, Cuba, September 22, 1845, by Holt & Owen. Sediment No. 6 is from this molasses."

A light colored molasses, having a very slightly acid taste; specific gravity 1.363, at 65°.6 F.

$e = 0.25$; $a = 23°.1$;
$d = 1.076$; $a'' = -7°.4$;
$t = 53°$ F.; $n = 0.9$.

Per cent. of cane sugar, 56.19.

37. Received from New York custom-house, and marked "64 hhds. molasses, marked ARy C$^{s}$. Imported in brig Brothers, from Neuvitas, by Holt & Owen, September 6, 1845. Nuevitas and St. Croix are considered the best molasses imported, and bring the highest price."

Specific gravity 1.336, at 64° F.

$e = 0.25$; $a = 27°.3$;
$d = 1.073$, $a'' = 5°.6$;
$t = 57°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 60.31.

38. Received from the New York custom-house, and marked "Cargo 19, lot 28—7 casks molasses, marked FE. Imported in brig Demarara, from Nuevitas, Cuba, September 22, 1845, by Holt & Owen."

A light colored, sweet molasses—rather thin for Nuevitas. Specific gravity 1.337, at 68°.3 F.

$e = 0.25$; $a = 24°.6$;
$d = 1.086$; $a'' = -7°.6$;
$t = 70°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 59.71.

39. Received from the New York custom-house, and marked "77 casks molasses, marked JG, imported in brig Brothers from Nuevitas, September 6, 1845, by Brett & Vose. Nuevitas brings the highest price in this market."

Specific gravity 1.368, at 64°.6 F.

$e = 0.25$; $a = 20°.4$;
$d = 1.086$; $a'' = -5°.4$;
$t = 53°$. F.; $n = 0.9$.

Per cent. of cane sugar, 46.81.

*Porto Rico molasses.*

40. Received from the New York custom-house, and marked "163 casks molasses, imported September 2, 1845, in brig Aldrich, from Porto Rico, by Chastelain & Ponvert. No sediment in this lot."

A reddish brown, perfectly sweet molasses; specific gravity 1.365, at 65°.5 F.

$e = 0.25$; $a = 21°.4$;
$d = 1.077$; $a'' = -7°.4$;
$t = 44°.7$; $n = 0.9$.

Per cent. of cane sugar, 53.07.

41. Received from the New York custom-house, and marked "44 casks Porto Rico molasses, imported September 6, 1845, in brig Wallace, from Guayama, P. R., by G. Wheelwright."

A rather dark colored molasses, having a slightly acid taste; specific gravity 1.3695, at 66°.2 F.

$e = 0.25$; $a = 21°.2$;
$d = 1.081$; $a'' = -7°.2$;
$t = 56°$ F.; $n = 0.9$.

Per cent. of cane sugar, 51.5.

*Molasses from Ponce, P. R.*

42. Received from the New York custom-house, and marked "29 casks molasses, permitted without mark, imported August 6, 1845, in brig Overman, from Ponce, P. R., by P. Harmony, Nephews & Co. Very little fermentation in this molasses."

Specific gravity 1.377, at 64°.7 F.

$e = 0.25$; $a = 22°.7$;
$d = 1.081$; $a'' = -7°.6$;
$t = 47°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 55.60.

43. Received from the Philadelphia custom-house, and marked "Sample of molasses in puncheons, per brig Sydney, from Ponce, P. R., consigned to Soutter and Broughton, Philadelphia, September 10, 1845."

A light colored molasses, having a heavy sediment in the bottom of the bottle, and a peculiar vinous or alcoholic taste; specific gravity 1.358, at 61° F.

$e = 0.25$; $a = 26°.9$;
$d = 1.087$; $a'' = -7°.3$;
$t = 60°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 62.14.

44. Received from the custom house Philadelphia, and marked "Sample of molasses in hogsheads, imported in the schooner Caroline, from Ponce, P. R., consigned to William S. Boyd, Philadelphia, September 2, 1845."

A molasses having a dark brownish red color, slightly acid taste, and a rather heavy sediment in the bottle; specific gravity 1.374, at 66°.9 F.

$e = 0.25$; $a = 24°.1$;
$d = 1.077$; $a'' = -7°.7$;
$t = 61°.2$; $n = 0.9$.

Per cent. of cane sugar, 58.52.

45. Received from the Baltimore custom-house, and marked "Gauged from on board schooner William ———, Captain Shaw, Ponce, P. R. Consigned to Withington & Eastman. Weight per gallon $11\frac{1}{4}$ lbs.

A dark colored thin molasses, having a slightly acid taste and small. Specific gravity 1.371.

$e = 0.25$; $a = 25°.3$;
$d = 1.080$; $a'' = -7°.8$;
$t = 61°.4$ F.; $n = 0.9$.

Per cent. of cane sugar, 60.73.

46. Received from the Baltimore custom-house, and marked "Gauged from on board brig Francis, from Ponce, P. R. Consigned to Kirkland & Chace. Weight per gallon 11 lbs. August, 1845."

A rather light colored thick molasses, having a slightly vinous taste. Specific gravity 1.376, at 66°.5 F.

$e = 0.25$; $a = 19°.5$;
$d = 1.069$; $a'' = -6°.8$;
$t = 64°$ F.; $n = 0.9$.

Per cent. of cane sugar, 48.84.

47. Received from the custom-house, New York, and marked "Cargo 3, lot 5—30 casks molasses, marked B. Imported August 20, 1845, in brig Cordelia, from Ponce, P. R., by H. Southmayd & Son. Sediment No. — was taken from the same casks in a quiet state."

It has a bitter taste, and rather thin consistence; red color by transmitted light. Specific gravity 1.354.

$e = 0.25$; $a = 19°.6$;
$d = 1.060$; $a'' = -5°.3$;
$t = 69°$ F.; $n = 0.9$.

Per cent. of cane sugar, 46.55.

*Molasses from Mayaguez, P. R.*

48. Received from the New York custom-house, and marked "70 casks molasses, imported in brig Port Leon, from Mayaguez, P. R., September 22, 1845. No sediment in this lot."

Specific gravity 1.3715, at 66°.9 F.

$e = 0.25$; $a = 24°.1$;
$d = 1.083$; $a'' = -6°.2$;
$t = 47°.7$ F.; $n = 0.9$.

Per cent. of cane sugar, 55.24.

49. Received from the New York custom-house, and marked "267 puncheons molasses, imported in schooner Mars, Hill, master, from Mayaguez, P. R., by J. W. Culbert. September 15, 1845."

A light colored molasses, having a peculiar vinous taste. Specific gravity 1.366, at 66°.1 F.

$e = 0.25$; $a = 22°.8$;
$d = 1.081$; $a'' = -7°.8$;
$t = 56°$ F.; $n = 0.9$.

Per cent. of cane sugar, 54.91.

50. Received from the New York custom-house, and marked "Cargo 10, lot 15—123 casks molasses, marked '*Latimer, Fernandez & Co., Mayaguez, P. R.*' Imported in schooner Tuscarora, September 8, 1845, by Mason & Thompson. Sediment No. 25 is from the same casks."

A very light colored and perfectly sweet molasses, with a copious sediment in the bottom of the bottle. Specific gravity 1.362, at 66° F.

$e = 0.25$; $a = 22°.3$;
$d = 1.0749$; $a'' = -6°.7$;
$t = 60°.5$; $n = 0.9$.

Per cent. of cane sugar, 53.41.

61. Received from the Philadelphia custom-house, and marked "Sample of molasses per schooner Nonpareil, from Mayaguez, consigned to Mason and Kirkland; marked O. 18 puncheons."

A dark colored molasses, with an abundance of foreign matter in it. Specific gravity 1.3595, at 64°.5 F.

$e = 0.25$; $a = 21°.5$;
$d = 1.0786$; $a'' = -6°$;
$t = 60°.7$ F.; $n = 0.9$.

Per cent. of cane sugar, 50.38.

52. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, by Crocker & Sturgis, in the barque Archelaus, from Mayaguez, August 28, 1845."

A rather light colored molasses, of a thin consistence, and a very slightly acid taste. Specific gravity 1.3485, at 56°.8 F.

$e = 0.25$; $a = 23°.7$;
$d = 1.073$; $a'' = -7°.2$;
$t = 56°$ F.; $n = 0.9$.

Per cent. of cane sugar, 57.

53. Received from the custom-house, Baltimore, and marked "Gauged from on board schooner Gallant Mary, from Mayaguez, consigned to Kirkland & Chace. Weight per gallon 11 lbs. 6 oz. August 27, 1845."

A very light colored molasses, having a tolerably thick consistency, and a slightly acid taste. Specific gravity 1.370, at 70°.8 F.

$e = 0.25$; $a = 23°$;
$d = 1.072$; $a'' = -7°.4$;
$t = 54°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 56.20.

54. Received from the Philadelphia custom-house, and marked "Sample of molasses, per schooner Nonpareil, from Mayaguez, consigned to Mason & Kirkland; marked P. R. 42 puncheons."

A thin, watery, and rather dark colored molasses, with an abundance of chips and foreign matter in it; taste entirely sweet. Specific gravity 1.3447, at 63° F.

$e = 0.25$; $a = 21°.7$;
$d = 1.076$; $a'' = -5°.3$;
$t = 62°$ F.; $n = 0.9$.

Per cent. of cane sugar, 49.47.

*Molasses from Guayama, P. R.*

55. Received from the New York custom-house, and marked "161 casks molasses, permitted without mark, imported in schooner Thames, from Guayama, P. R., by Chastelain & Ponvert. This sample was taken when in a state of fermentation."

A dark colored molasses, having a very acid smell and taste. Specific gravity 1.354, at 63°.8 F.

$e = 0.25$; $a = 25°.8$;
$d = 1.0997$; $a'' = -7°.1$;
$t = 57°$; $n = 0.9$.

Per cent. of cane sugar, 60.33.

56. Received from the New York custom-house, and marked "161 casks molasses, permitted without mark, imported in schooner Thames, from Guayama, P. R., by Chastelain & Ponvert. This sample was taken in a quiet state, after standing 24 hours."

A quite light colored molasses, having a slight bitter taste. Specific gravity 1.376, at 66°.8 F.

$e = 0.25$; $a = 24°.2$;
$d = 1.083$; $a'' = -9°$;
$t = 64°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 60.95.

57. Received from the New York custom-house, and marked "73 casks molasses: no mark. Imported in brig Ansonia, from Guayama, P. R., September 6, 1845, by Chastelain and Ponvert."

A dark colored molasses, having a slightly acid taste; specific gravity 1.361, at 55°.5 F.

$e = 0.25$; $a = 21°.7$;
$d = 1.079$; $a'' = -7°.8$;
$t = 62°.3$ F.; $n = 0.9$.

Per cent. of cane sugar, 54.30.

57. Received from the New York custom-house, and marked "Cargo 4, lot 6—172 casks molasses, marked AF, Fantanzza. Imported August 28, 1845, in brig Russia, from Guayama, P. R., by J. B. Lasala & Co. Sediment No. 16 is from the same casks."

A slight fermentation has taken place; the odor from the bottle is quite sour, and the taste decidedly acid; the consistence is rather thin; specific gravity 1.362, at 66°.4 F.

$e = 0.25$; $a = 22°.3$;
$d = 1.079$; $a'' = -7°$;
$t = 40°$ F.; $n = 0.9$.

Per cent. of cane sugar, 53.82.

59. Molasses from Arecibo, P. R. Received from the custom-house, Baltimore, and marked "Gauged from on board brig Commerce, Captain W. B. Blanchard, from Arecibo; consigned to W. Howell & Son, 12th September, 1845."

A rather light colored molasses, having a vinous taste; specific gravity 1.376, at 70° F.

$e = 0.25$; $a = 19°.9$;
$d = 1.074$; $a'' = -6°.6$;
$t = 55°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 48.93.

60. Molasses from Naguabo, P. R. Received from the New York custom-house, and marked "56 hhds. molasses, imported in brig Sabine, from Naguabo, P. R., September 24, 1845, by John B. Lasala & Co."

A thin light colored molasses, having a perfectly sweet taste: specific gravity 1.367, at 58°.6 F.

$e = 0.25$; $a = 22°$;
$d = 1.082$; $a'' = -8°.4$;
$t = 60°.5$; $n = 0.9$.

Per cent. of cane sugar, 55.89.

61. Molasses from Surinam. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, in the brig Massasoit, from Surinam, by D. & F. Mickerson, August 29, 1845."

A dark colored molasses, of a thin consistence, and acid taste and odor; specific gravity 1.3375, at 55°.8 F.

$e = 0.25$; $a = 20°.9$;
$d = 1.076$; $a'' = -6°.6$;
$t = 52°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 50.66.

62. Molasses from St. Croix. Received from the New York custom-house, and marked "190 casks of molasses, marked AC, imported in barque Isabella, from St. Croix, September 4, by Alsop & Chauncey."

A light colored molasses, having a very slight acid taste; fermentation has taken place; specific gravity 1.376, at 60° F.

$e = 0.25$; $a = 21°.9$;
$d = 1.0798$; $a'' = -8°.6$;
$t = 50°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 56.24.

63. Molasses from St. Croix. Received from the custom-house, New York, and marked "Cargo 17, lot 25—30 casks molasses, marked [B.] Imported in the schooner Empire, from St. Croix, September 23, 1845, by B. De Forrest & Co. Sediment No. 19 is from this molasses."

A light colored molasses, of a rather thin consistence, and a sweet taste; specific gravity 1.340, at 66° F.

$e = 0.25$; $a = 20°.8$;
$d = 1.072$; $a'' = -7°.1$;
$t = 66°.8$ F; $n = 0.9$.

Per cent. of cane sugar, 51.65.

64. Molasses from St. Thomas. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, in the schooner Sarah Elizabeth, from St. Thomas, by J. H. Hicks & Co., October 6, 1845."

A light colored thick molasses, having a sweet taste; specific gravity 1.378, at 51° F.

$e = 0.25$; $a = 24°.7$;
$d = 1.074$; $a'' = -7°.1$;
$t = 60°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 58.54.

65. Molasses from St. Thomas. Received from Baltimore custom-house, and marked "Gauged from on board schooner Comet, Captain Binney, from St. Thomas, consigned to Johnson & Traverse; weight per gallon, 11 pounds 2 ounces; August 23, 1845."

A rather dark colored molasses, having a vinous taste; specific gravity 1.355, at 70°.8 F.

$e = 0.25$; $a = 23°.8$;
$d = 1.064$; $a'' = -6°.8$;
$t = 67°$ F.; $n = 0.9$.

Per cent. of cane sugar, 75.97.

66. Molasses from St. John's. Received from the custom-house, Boston, and marked "Imported into the port of Boston and Charlestown, August 19, 1845, by Judson Andrews & Co., in the schooner Willis Putnam, from St. John's, P. R."

A thick dark colored molasses, having a slightly vinous taste; specific gravity 1.357, at 55°.6 F.

$$e = 0.25; \quad a = 21°.6;$$
$$d = 1.076; \quad a'' = -6°.9;$$
$$t = 54°.2 \text{ F.}; \quad n = 0.9.$$

Per cent. of cane sugar, 52.49.

67. Molasses from St. John's. Received from the custom-house, Boston, and marked "Imported into the district of Boston and Charlestown, in the Brig Lucy Ellen, from St. John's, N. B., by Samuel Cliland, October 11, 1845."

A black colored molasses, of a thin consistence, and a vinous taste; specific gravity 1.353, at 55°.5 F.

$$e = 0.25; \quad a = 21°;$$
$$d = 1.073; \quad a'' = -6° 2;$$
$$t = 52°.5 \text{ F.}; \quad n = 0.9.$$

Per cent. of cane sugar, 50.17.

68. Molasses from Xibara. Received from the custom-house, New York, and marked "219 casks molasses, imported in schooner Hope, from Xibara, October 11, 1845, by Daniel Curtis, jr."

A light colored molasses, having a sweet taste. A slight fermentation has taken place. Specific gravity 1.369, at 64°.8 F.

$$e = 0.25; \quad a = 21°.7;$$
$$d = 1.083; \quad a'' = -9°.2;$$
$$t = \quad n = 0.9.$$

Per cent. of cane sugar, 56.89.

69. Molasses from Humacoa. Received from the New York custom-house, and marked "221 casks molasses, imported in brig Will, from Humacoa, P. R., September 20, 1845, by J. B. Lasala & Co."

A light colored molasses, having a perfectly sweet taste; specific gravity 1.372, at 59° F.

$$e = 0.25; \quad a = 24°.2;$$
$$d = 1.076; \quad a'' = -8°.4;$$
$$t = 53°.4 \text{ F.}; \quad n = 0.9.$$

Per cent. of cane sugar, 50.13.

70. *Miel de purga.* Clayed molasses brought from the Saratoga estate, Cuba, and analyzed in Philadelphia.

A rather dark colored and thick molasses, having a slightly acid taste; specific gravity 1.361.

$e = 0.25$; $a = 20°.3$;
$d = 1.062$; $a'' = -6°.25$;
$t = 70°$ F.; $n = 0.9$.

Per cent. of cane sugar, 49.50.

71. *Miel de descarga.* From the Saratoga estate.

A rather light colored molasses, of ordinary consistency, and having a slightly acid vinous taste; specific gravity 1.340.

$e = 0.25$; $a = 21°.2$;
$d = 1.0607$; $a'' = -6°$;
$t = 70°$ F.; $n = 0.9$.

Per cent. of cane sugar, 50.68.

72. New Orleans plantation molasses. Obtained in Louisiana.

A molasses of ordinary consistency, having a slightly acid taste, and rather dark color. When poured, a foam formed on the surface. Specific gravity 1.352, at 81°.7 F.

The extractive matter was precipitated by sub-acetate of lead, and the solution filtered through boneblack.

$e = 0.25$; $a = 22.07$;
$d = 1.0707$; $a'' = -6°.2$;
$t = 71°.5$; $n = 0.9$.

Per cent. of cane sugar, 53.18.

73. Sugar-house molasses, Philadelphia. From a grocer.

A dark, thick molasses, having a decidedly burnt taste and odor; specific gravity 1.495.

$e = 0.50$; $a = 37°.3$;
$d = 1.171$; $a'' = -9°$;
$t =$ ; $n = 0.8$.

Per cent. of cane sugar, 40.03.

74. New Orleans sugar-house molasses.

A rather dark colored and very thick molasses, having a very distinct burnt taste and odor; slightly translucent; specific gravity 1.4002, at 81° F.

$e = 0.25$; $a = 18°.8$;
$d = 1.073$; $a'' = 4°.8$;
$t = 80°$ F.; $n = 0\ 9$.

Per cent. of cane sugar, 43.53.

75. *Sirup de batterie*, or *melado*. Brought from the *Ingenio Saratoga*, Cuba.

Specific gravity 1.337, at 84°.8 F.

$e = 0.25$; $a = 25°.2$;
$d = 1.056$; $a'' = -7°.4$;
$t = 82°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 60.57.

76. Lovering's *sirup;* drippings from loaves; Philadelphia.

A light reddish yellow, almost transparent sirup; specific gravity, 1.3. A perfectly white sugar had settled in the bottle.

$e = 0.50$; $a = 55°.5$;
$d = 1.1601$; $a'' = -14°.7$;
$t =$ $n = 0.9$.

Per cent. of cane sugar, 59.76.

77. Lovering's second quality sirup, Philadelphia.

A cherry red, translucent sirup, having a very slight burnt taste and odor. Specific gravity, 1.4.

$e = 0.50$; $a = 43°.4$;
$d = 1.168$; $a'' = -9.8$;
$t =$ $n = 0.9$.

Per cent. of cane sugar, 44.86.

MOLASSES SEDIMENTS.

1. Sediment from molasses, No. 21. Received from the New York custom-house.

The supernatant molasses quite acid, and the sediment fine grained and somewhat pasty; the taste acid, apparently in consequence of the intermixed molasses.

$e = 0.25$; $a = 32°$;
$d = 1.090$; $a'' = -9°$;
$t = 21°.5$ C.; $n = 0.9$.

Per cent. of cane sugar, 74.34.

2. Sediment from Cienfuegos molasses. Received from the Philadelphia custom-house.

A brownish yellow sediment, having a slightly acid odor, and partly pasty, partly granular; gritty between the fingers.

$e = 0.25$; $a = 31°.2$;
$d = 1.0878$; $a'' = -9°.4$;
$t = 19°.6$ C.; $n = 0.9$.

Per cent. of cane sugar 73.90.

3. Sediment from Trinidad de Cuba molasses, No. 23. A light

yellow, almost entirely pasty mass, having no perceptible grit between the fingers or teeth.

$e = 0.25$; $a = 33°.2$;
$d = 1.0866$; $a'' = -10°$;
$t = 71°$ F.; $n = 0.9$.

Per cent. of cane sugar, 78.62.

4. Sediment from molasses, No. 24.

The supernatant molasses unusually thin and watery; the sediment of itself dark colored, of a gritty and coarse grain, and to the taste slightly acid.

$e = 0.25$; $a = 35°$;
$d = 1.0925$; $a'' = -9°$;
$t = 19°.25$ C.; $n = 0.9$.

Per cent. of cane sugar, 79.55.

5. Sediment from molasses (No. 33) from Sagua la Grande.

The exposed surface of this sediment was dark colored, hard, and dry. It was removed, and the analysis made of the interior, which was light colored and dryer than the other sediments analyzed.

$e = 0.25$; $a = 33°.15$;
$d = 1.0982$; $a'' = -11°.95$;
$t = 55°.4$ C.; $n = 0.9$.

Per cent. of cane sugar, 81.58.

6. Sediment from molasses, No. 36.

A light colored and apparently three-fourths pasty mass; the supernatant molasses entirely sweet.

$e = 0.25$; $a = 31°.8$.
$d = 1.085$; $a'' = -9°$.
$t = 83°.5$ F.; $n = 0.9$.

Per cent. of cane sugar 74.83.

7. Sediment from molasses (No. 38) from Nuevitas.

A dark colored dirty mass; three fourths granular, and of good grain; crystals of sugar occurring here and there in the mass.

$e = 0.25$; $a = 32°.2$;
$d = 1.0836$; $a'' = -9°.1$;
$t = 89°$ F.; $n = 0.9$.

Per cent. of cane sugar, 75.34.

8. Sediment from Nuevitas molasses.

A dark colored sediment, entirely granular, and of a very good grain; gritty between the teeth.

$e = 0.25$; $a = 29°.6$;
$d = 1.0886$; $a'' = -10°$;
$t = 20°$ C.; $n = 0.9$.

Per cent. of cane sugar, 72.20.

9. Sediment from Nuevitas molasses.

A light colored granular sediment, having a very good grain, and not at all pasty; gritty between the fingers. The molasses was separated by putting the sediment into a linen cloth, and allowing the molasses to flow through. It was suffered to remain so for nearly twenty-four hours, and the driest portions then selected for analysis.

$e = 0.25$; $a = 35°.6$;
$d = 1.088$; $a'' = -9°.3$;
$t = 24°.6$ C., $n = 0.9$.

Per cent. of cane sugar, 81.47.

10. Sediment from Nuevitas molasses.

A very light yellow, half pasty, half granular mass; unusually free from foreign matter.

$e = 0.25$; $a = 34°.1$;
$d = 1.090$; $a'' = -9°.2$;
$t = 86°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 78.40.

11. Sediment from molasses, No. 41.

A dark colored granular mass, with a hard, strong, and gritty grain. It was impossible to drain off all the molasses by the process used in the other sediments; this resembling brown sugar of good grain, mixed with molasses.

$e = 0.25$; $a = 30°.3$,
$d = 1.0871$; $a'' = -7°.5$;
$t = 20°$ C.; $n = 0.9$.

Per cent. of cane sugar, 68.59.

12. Sediment from Porto Rico Rico molasses.

Consists of a half pasty, half granular mass, containing lumps of granulated sugar; gritty when rubbed between the fingers.

$e = 0.25$; $a = 33°6$;
$d = 1.0916$; $a'' = -9°.4$;
$t = 23°.3$ C; $n = 0.9$.

Per cent. of cane sugar, 77.87.

13. Sediment from molasses, No. 42.

A semi-granular, dark colored sugar, having a grain only passably good, and an odor like that of molasses.

$e = 0.25$; $a = 31°.8$;
$d = 1.093$; $a'' = -9°.2$;
$t =$ ; $n = 0.9$.

Per cent. of cane sugar, 74.19.

14. Sediment from molasses, No. 49.

A light yellow colored sediment, apparently about four-fifths granular, and having a very good, hard grain; gritty between the fingers.

$e = 0.25$; $a = 33°.25$;
$d = 1.0905$; $a'' = -10°$;
$t = 25°$ C.; $n = 0.9$.

Per cent. of cane sugar, 78.54.

15. Sediment from molasses, No. 49.

A mixture of pasty sediment and supernatant molasses, from sediment No. 14; not the slightest grit perceptible by rubbing between the fingers. It has a yellow color, and sufficient fluidity to allow it to be poured.

$e = 0.25$; $a = 30°.7$;
$d = 1.0853$; $a'' = -8°.2$;
$t = 26°$ C.; $n = 0.9$.

Per cent. of cane sugar, 70.80.

16. Sediment from Guayama molasses, No. 58.

A light colored, pasty mass; grain very inferior. Not gritty between the fingers.

$e = 0.25$; $a = 33°.5$;
$d = 1.0908$; $a'' = -8°.6$;
$t = 22°$ C.; $n = 0.9$.

Per cent. of cane sugar, 76.16.

17. Sediment from molasses, No. 60.

A light yellow colored, and apparently one-third granular mass.

$e = 0.25$; $a = 32°$;
$d = 1.0914$; $a'' = -10.2$;
$t = 71°$ F.; $n = 0.9$.

Per cent. of cane sugar, 76.67.

18. Sediment from molasses, No. 62.

A brownish yellow sediment, about three-fourths granular, and having an odor like that of molasses.

$e = 0.25$; $a = 32°.$;
$d = 1.084$; $a'' = -9°.9$;
$t = 20°.8$ C.; $n = 0.9$.

Per cent. of cane sugar, 76.58.

19. Sediment from St. Croix molasses, No. 63.

A very light yellow, and altogther pasty mass; much drier than generally occurs.

$e = 0.25$; $a = 33°.7$;
$d = 1.0907$; $a'' = -9°.3$;
$t = 87°$ F.; $n = 0.9$.

Per cent. of cane sugar, 74.17.

20. Sediment from molasses from Xibara, No. 68.

A reddish brown, half pasty, half granular mass, in a state of fermentation; molasses mixed up with it.

$e = 0.25$; $a = 30°.6$;
$d = 1.0857$; $a'' = -9°$;
$t = 70°$ F.; $n = 0.9$.

Per cent. of sugar-cane, 73.49.

21. Sediment from molasses, No. 69.

A brownish yellow sediment, about two-thirds granular, and of quite a good grain.

$e = 0.25$; $a = 28°.3$;
$d = 1.082$; $a'' = -8°.8$;
$t = 86°.5$; $n = 0.9$.

Per cent. of cane sugar, 67.90.

22. Molasses sediment.

A deep yellow colored, and quite granular mass; gritty between the fingers, and has an odor entirely sweet.

$e = 0.25$; $a = 31°.7$;
$d = 1.0884$; $a'' = -9°$;
$t = 24°.6$ C.; $n = 0.9$.

Per cent. of sugar cane, 73.97.

23. Molasses sediment.

A brownish yellow sediment, having a fine large grain, and an odor like that of molasses; gritty when rubbed between the fingers.

$e = 0.25$; $a = 35°$;
$d = 1.0919$; $a'' = -9°.4$;
$t = 23°.2$ C.; $n = 0.9$.

Per cent. of cane sugar, 80.29.

24. Molasses sediment, from the New York custom-house. It appears to consist of cane sugar only, and has a hard, gritty grain. A twenty-five per cent. solution was first heated with fine animal black, and then decolorized.

$e = 0.25$; $a = 33°.75$;
$d = 1.0936$; $a'' = -10°.75$;
$t = 23°.3$ C.; $n = 0.9$.

Per cent. of cane sugar, 80.63.

25. Sediment from molasses, No. 50.
Consists of soft pasty matter, mixed with granular cane sugar in nearly equal proportions; the taste a pure sweet.

$e = 0.25$; $a = 31°$;
$d = 1.0875$; $a'' = -9°$;
$t = 23°$ C., $n = 0.9$.

Per cent. of cane sugar, 72.83.

26. Molasses sediment.
The supernatant molasses had a pure sweet taste. When a film of it was evaporated on glass, it deposited a thick coating apparently of sugar. The solid matter of the sediment seemed to be good crystalline sugar, of a remarkably strong and gritty grain. A portion of this sediment being drained of molasses, was washed with a saturated solution of pure sugar, to remove all molasses. It then consisted of white, hard, gritty, and well granulated sugar, which, after drying, gave the following result:

$e = 0.25$; $a = 39°.5$;
$d = 1.0974$; $a'' = -12°$;
$t = 23°$ C.; $n = 0.9$.

Per cent. of cane sugar, 93.

27. Molasses sediment.
A brownish yellow, semi-granular mass, having a tolerable grain; more granular than pasty; the odor like that of molasses.

$e = 0.25$; $a = 29°.8$;
$d = 1.093$; $a'' = -10°.1$;
$t = 22°.8$ C.; $n = 0.9$.

Per cent. of cane sugar, 72.31.

28. Molasses sediment.

Light colored, of a sweet taste, and a fine but firm grain; it seems to consist chiefly of finely divided sugar.

$e = 0.25$; $a = 31°$;
$d = 1.0945$; $a'' = -10°$;
$t = 20°$ C.; $n = 0.9$.

Per cent. of cane sugar, 74.28.

29. Molasses sediment.

The supernatant molasses pure sweet; the sediment apparently strong grained sugar, gritty, and distinctly granular between the fingers; taste perfectly sweet.

$e = 0.25$; $a = 32°.5$;
$d = 1.0904$; $a'' = -10°$;
$t = 20°$ C.; $n = 0.9$.

Per cent. of cane sugar, 77.23.

30. Molasses sediment.

The supernatant molasses sirupy, but somewhat acid; the sediment soft grained and pasty; its taste sweet and farinaceous.

$e = 0.25$; $a = 31°.5$;
$d = 1.0916$; $a'' = 10°$;
$t = 21°.5$ C.; $n = 0.9$.

Per cent. of cane sugar, 75.28.

SUGARS.

1. Sugar from Havana.—Received from the custom-house, Philadelphia, and marked "White sugar, (in 5 boxes,) from Havana, per the barque Elizabeth, J. Remington, master; mark [P.] Consigned to J. & J. Peterson. August 28, 1845."

White, dry, and of a delicate, fresh flavor; strong grained; fine, but gritty.

$e = 0.25$; $a = 42°.5$;
$d = 1.1078$; $a'' = 13.5$;
$t = 22°$ C.; $n = 0.9$.

Per cent. of cane sugar, 99.5

2. Sugar from St. Jago de Cuba.—Received from the custom-house, Boston, and thus labelled: "Sample of 50 boxes clayed sugar, imported into Boston from St. Jago de Cuba, in the brig Jno. H. Stephens, by Chamberlain & Co., September 30, 1845; duty 2½ cents per pound."

A white and dry sugar, having an excellent grain.

$e = 0.25$; $a = 43°.36$;
$d = 1.1105$; $a'' = 12°.78$;
$t = 60°$ F.; $n = 0.9$.

Per cent. of cane sugar, 99.

3. Sugar from Trinidad.—Received from the custom-house, Boston, and marked "Sample of 20 boxes white sugar, imported into Boston from Trinidad, in the barque Franklin, by Gossler & Co., October 11, 1845; duty 4 cents per pound."

A white and dry sugar, having an excellent grain, and almost purely white.

$e = 0.25$; $a = 40°$;
$d = 1.1094$; $a'' = -13°.3$;
$t = 64°$ F.; $n = 0.9$.

Per cent. of cane-sugar, 95.32.

4. Sugar from Matanzas.—Received from the Philadelphia custom-house, and marked "Sample of (brown sugars) 550 boxes sugar from Matanzas, imported in the brig Balize, Capt. Searles. Consigned to Borie & McKean, marked [B.] October 1, 1845."

A very light-colored, dry sugar, nearly pure white, and having a very good grain, gritty, and a fine, fresh taste.

$e = 0.25$; $a = 41°.4$;
$d = 1.1031$; $a'' = -12°.4$;
$t = 79°.5$ F.; $n = 0.9$.

Per cent. of cane-sugar, 96.58.

5. Sugar from Nuevitas.—Received from the New York custom-house, and marked "Brig Demarara, Blachard, master, from Nuevitas; arrived September 22, 1845; FE, 78 boxes brown sugar, imported by Holt & Owen; duty 2½ cents per pound."

A dry, very light-colored sugar, being nearly pure white, and having a good grain, and gritty.

$e = 0.25$; $a = 41°.7$;
$d = 1.1039$; $a'' = -12°.7$;
$t = 81°$ F.; $n = 0.9$.

Per cent. of cane sugar, 97.55.

6. Sugar from Mansanilla.—Received from the custom-house, Boston, and marked "Sample of 87 boxes white sugar, imported into Boston from Mansanilla, in the brig Nereus, by Homer & Sprague, October 6, 1845; duty 4 cents per pound."

A dry, white, bright, crystalline sugar, having an excellent grain.

$e = 0.25$; $a = 41°.6$;
$d = 1.1026$; $a'' = -12°.3$;
$t = 86°.5$ F.; $n = 0.9$

Per cent. of cane sugar, 96.68.

7.—Sugar from Pernambuco.—Received from the custom-house, Philadelphia, and marked "Sample of brown sugar, in sacks, from Pernambuco, per the brig R. F. Lopos, Tassot, master; mark, L. Consigned to Samuel A. Lewis & Brother. September 8, 1845."

Nearly white, of good grain, with lumps interspersed, and somewhat moist.

$e = 0.25$; $a = 42°$;
$d = 1.1065$; $a'' = -14°.5$; (?)
$t = 20°$ C.; $n = 0.9$.

Per cent. of cane sugar, 100. (?)

*Quebrado florete.*

8. Sugar from Havana.—Received from the custom-house, New York, and marked "Ship Adelaide, Adams, master, from Havana; arrived September 15, 1845; J M & C, 67 boxes brown sugar, imported by J. Matthews & Co.; duty 2½ cents per pound."

A dry, light colored sugar, nearly white, having a good, strong grain, with small hard lumps occurring.

$e = 0.25$; $a = 42°.25$;
$d = 1.1061$; $a'' = -12°.8$;
$t$ 75° F.; $n = 0.9$.

Per cent. of cane-sugar, 98.58.

9. Sugar from St. Jago de Cuba.—Received from the Philadelphia custom-house, and marked "Brown sugar, in boxes, per the brig Adela, Long, master, from St. Jago de Cuba; mark, Plantation *Blanco*, J. J. B., September 17, 1845."

So slightly colored that it might be called white; grain dry, fine, and gritty; taste without freshness and aroma.

$e = 0.25$; $a = 42°.5$;
$d = 1.1090$; $a'' = -12°.25$;
$t = 20°$ C.; $n = 0.9$.

Per cent. of cane-sugar, 97.64.

10. Sugar from Mansanilla.—Received from the custom-house, Boston, and marked "Sample of 105 boxes brown sugar, imported into Boston, from Mansanilla, in the brig Nereus, by Homer & Sprague. October 6, 1845. Duty 2½ cents per lb."

A dry, very light colored sugar, almost pure white, and having an excellent grain, with crystalline lumps occurring.

$e = 0.25$; $a = 42°.44$;
$d = 1.1086$; $a'' = -12°.7$;
$t = 65°.7$ F.; $n = 0.9$.

Per cent. of cane sugar, 98.29.

11. Sugar from Cienfuegos.—Received from the custom-house, Boston, and marked "Sample of 42 boxes brown sugar, imported into Boston from Cienfuegos, in the brig Eliza Burgess, by Benj. Burgess & Sons. August 25, 1845. Duty 2½ cents per lb."

A dry white sugar, nearly pure white, having an excellent grain, and a crystalline appearance.

$e = 0.25$; $a = 41°.7$;
$d = 1.1022$; $a'' = -12°.30$;
$t = 85°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 96.94.

12. Sugar from Pernambuco.—Received from the custom-house, Boston, and marked "Sample of 600 bags brown sugar, imported into Boston from Pernambuco, in the ship Catharine, by Robt. G. Shaw & Co. September 8, 1845. Duty 2½ cents per lb."

A white sugar, (not quite pure white,) having a very good grain; large hard lumps occurring frequently.

$e = 0.25$; $a = 42°.7$;
$d = 1.1054$; $a'' = -12°.1$;
$t = 69°$ F.; $n = 0.9$.

Per cent. of cane sugar, 98.08.

13. Sugar from Pernambuco.—Received from the custom-house, Boston, and marked "Sample of 330 bags brown sugar, imported into Boston from Pernambuco, in the ship Catharine, by Robt. G. Shaw & Co. September 8, 1845. Duty 2½ cents per lb."

A light colored (almost pure white) dry sugar, having a very good grain. The copper test gives a red precipitate.

$e = 0.25$; $a = 42°$;
$d = 1.1065$; $a'' = -12°.25$;
$t = 71°.1$ F.; $n = 0.9$.

Per cent. of cane sugar, 97.

14. Sugar from Pernambuco.—Received from the custom-house, Boston, and marked "Sample of 953 bbls. brown sugar, imported into Boston from Pernambuco, in the ship Catharine, by Robt. G. Shaw & Co. September 8, 1845. Duty 2½ cents per lb."

A very light colored, (almost white,) dry, clayed sugar, having a very good grain.

$e = 0.25$; $a = 41°.9$;
$d = 1.1058$; $a'' = -12°,2$;
$t = 71°$ F.; $n = 0.9$.

Per cent. of cane sugar, 96.74.

*Quebrado* 1*a*.

15. Sugar from Havana.—Received from the custom-house, New York, and marked "Ship Adelaide, Adams, master, from Havana, arrived September 15, 1845. Mark, S. & C., 3 boxes brown sugar, imported by Sturges & Co. Duty 2½ cents per lb."

A very light colored (nearly pure white) sugar, having an excellent grain; small hard lumps very frequently occurring.

$e = 0.25$; $a = 41°.75$;
$d = 1.103$; $a'' = -12°.25$;
$t = 82°$ F.; $n = 0.9$.

Per cent. of cane sugar, 96.89.

16. Sugar from St. Jago de Cuba.—Received from the custom-house, New York, and marked "Imported in schooner Charran, from St. Jago de Cuba, by Jonathan Thompson, jr., 40 boxes sugar. Jugua, Tr. October 9, 1845. Duty 2½ cents per lb."

A dry, very light colored sugar, (almost pure white,) and having an excellent grain.

$e = 0.25$; $a = 42°.9$;
$d = 1.107$; $a'' = -12°.8$;
$t = 73°$ F.; $n = 0.9$.

Per cent. of cane sugar, 99.56.

17. Sugar from St. Jago de Cuba.—Received from the custom-house, New York and marked " Imported in schooner Charran, from St. Jago de Cuba, October 9, 1845, by Jonathan Thompson, jr., 135 boxes sugar, marked Tr [P. D. O. & B. C. O.] *Dosramos*. Duty 2½ cents per lb."

A very light colored, dry sugar, having a very good grain.

$e = 0.25$; $a = 41°.2$;
$d = 1.108$; $a'' = -13°.25$;
$t = 62°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 97.40.

18. Sugar from St. Jago de Cuba.—Received from the custom-house, Boston, and marked "Sample of 32 boxes first quality brown sugar, imported into Boston from St. Jago de Cuba, in the brig General Brooks, by John S. Hill, August 12, 1845. Duty 2½ cents per lb."

A very light colored, dry sugar, having an excellent grain ; almost pure white.

$e = 0.25$; $a = 42°.3$;
$d = 1.1085$; $a'' = -13°.08$;
$t = 66°$ F.; $n = 0.9$.

Per cent. of cane sugar, 99.

19. Sugar from St. Jago de Cuba.—Received from the custom-house, Boston, and marked "Sample of 67 boxes first quality brown sugar, imported into Boston from St. Jago de Cuba, in the brig John H. Stephens, by John S. Hill, September 30, 1845. Duty 2½ cents per lb."

A light colored (almost white) sugar, having a very good grain, with hard lumps occurring frequently.

$e = 0.25$; $a = 40°.92$;
$d = 1.1066$; $a'' = -13°.38$;
$t = 65°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 97.26.

20. Sugar from Trinidad.—Received from the custom-house, Philadelphia, and marked "Brown sugar in boxes, from Trinidad, per schooner Fashion, Howard, master, marked *S*, and consigned to S. & W. Welsh, Philadelphia, August 25, 1845."

In color so nearly white, that it might readily be sold as such; grain strong, fine, dry, and pulverulent. It contains lumps which are so compact that they resemble fragments of refined loaf sugar in solidity; the taste is also that of the latter.

$e = 0.25$; $a = 42°.25$;
$d = 1.1059$; $a'' = -12°.5$;
$t = 22°$ C.; $n = 0.9$.

Per cent. of cane sugar, 98.87.

21. Sugar from Trinidad.—Received from the custom-house, Boston, and marked "Sample of 459 boxes of brown sugar, imported into Boston, from Trinidad, in the brig Smyrna, by Philo S. Shelton, September 30, 1845; duty 2½ cents per pound."

A light colored, almost white sugar, having a very good grain.

$e = 0.25$; $a = 42°.5$;
$d = 1.1105$; $a'' = -13$;
$t = 65.5$; $n = 0.9$.

Per cent. of cane sugar, 98.14.

22. Sugar from Nuevitas.—Received from the custom-house, New York and marked "Brig Amaranda, Avery, master, from Nuevitas;

arrived September 26, 1845; *SV*, 200 boxes brown sugar imported by Holt & Owen; duty 2½ cents per pound."

A dry, grayish white sugar, having a very good grain; small lumps of excellent grain occurring.

$e = 0.25$; $a = 42°$;
$d = 1.1046$; $a'' = -11°.3$;
$t = 79°$ F.; $n = 0.9$.

Per cent. of cane sugar, 95.31.

23. Sugar from Pernambuco.—Received from the custom-house, Boston, and marked "Sample of 170 bags brown sugar, imported into Boston from Pernambuco, in the ship Catharine, by Robert G. Shaw & Co., September 8, 1845; duty 2½ cents per pound."

A grayish white and slightly moist sugar, having a mealy feeling between the fingers; hard lumps occurring frequently.

$e = 0.25$; $a = 40°$;
$d = 1.1057$; $a'' = -12°$;
$t = 81°$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.

24. Sugar from Pernambuco.—Received from the custom-house, Boston, and marked "Sample of 717 bbls. brown sugar, imported into Boston from Pernambuco, in the ship Catharine, by Robert G. Shaw & Co., September 8, 1845; duty 2½ cents per pound."

A grayish white, slightly moist sugar, having a tolerable grain only; lumps of a hard grain occurring in it.

$e = 0.25$; $a = 40°.3$;
$d = 1.1053$; $a'' = -12°.2$;
$t = 73°$ F.; $n = 0.9$.

Per cent. of cane sugar 94.

*Quebrado 2a.*

25. Sugar from Havana.—Received from the custom-house, Philadelphia, and marked "Sugar in boxes, per the brig Elizabeth, Power, master, from Havana, consigned to John F. Ohl & Son; marked *O & S*, September 12, 1845.

The color but slightly brown; grain fine, dry, and pulverulent; aroma rather strong for a clayed sugar.

$e = 0.25$; $a = 42°$;
$d = 1.1083$; $a'' = -11°.5$;
$t = 20°$ C.; $n = 0.9$.

Per cent. of cane sugar, 95.42.

26. Sugar from Havana.—Received from the custom-house, New York, and thus labelled: "Ship Adelaide, from Havana; arrived September 15, 1845; *A J*, 38 boxes brown sugar, imported by Spofford, Tileston & Co.; duty 2½ cents per pound."

A very light colored, dry sugar, having a very good grain, with small hard lumps occurring frequently; apparently clayed.

$e = 0.25$; $a = 41°.2$;
$d = 1.104$; $a'' = 12°.4$;
$t = 80°$ F.; $n = 0.9$.

Per cent of cane sugar, 96.1.

27. Sugar from St. Jago de Cuba.—Received from custom-house, Philadelphia, and marked "Brown sugar in boxes, per the brig Mary Helen, West, master, from St. Jago de Cuba; consigned to Robert Adams & Co., September 12, 1845."

Grain fine, dry, and gritty; firm between the teeth; aroma fresh and delicate.

$e = 0.25$; $a = 42°$;
$d = 1.1085$; $a'' = -14°$;
$t = 26°$ C.; $n = 0.9$.

Per cent. of cane sugar, 89. (?)

28. Sugar from St. Jago de Cuba.—Received from the custom-house, Philadelphia, and marked "Clayed sugar in boxes, from St. Jago de Cuba, per the brig Vulture, Mayo, master, marked V; consigned to Burling & Dixon, August 28, 1845."

Color very light brown; grain strong, dry, fine, and gritty.

$e = 0.25$; $a = 43°$;
$d = 1.1065$; $a'' = -12°.5$;
$t = 23°.5$ C.; $n = 0.9$.

Per cent. of cane sugar, 98. (?)

29. Sugar from St. Jago de Cuba.—Received from the custom-house, New York, and marked "Imported in the schooner Charran, from St. Jago de Cuba, October 17, 1845, by Jonathan Thompson, jr., 50 bbls. brown sugar, marked Tт; duty 2½ cents per pound."

A dry, whitish yellow sugar, of a very good and hard grain.

$e = 0.25$; $a = 40°$;
$d = 1.1035$ $a'' = -12°$;
$t = 79°.5$; $n = 0.9$.

Per cent. of cane sugar, 93.31.

30. Sugar from St. Jago de Cuba.—Received from the custom-house, New York, and marked "Imported in schooner Charran, from St. Jago de Cuba, October 10, 1845, by Richard Irvin, 25 boxes sugar, marked RF; duty 2½ cents per pound."

A dull yellow color; slightly moist, with hard lumps occuring; grain tolerably good.

$e = 0.25$; $a = 38°.3$;
$d = 1.100$; $a'' = -11°$;
$t = 83°$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.64.

31. Sugar from St. Jago de Cuba.—Received from the custom-house, Boston, and marked "Sample of 233 boxes second quality brown sugar, imported into Boston, from St. Jago de Cuba, in the brig Jno. H. Stephens, by John S. Hill, September 30, 1845; duty 2½ cents per pound."

A grayish yellow, rather dry sugar, having a good grain; appearance not crystalline.

$e = 0.25$; $a = 41°.75$;
$d = 1.1046$; $a'' = -11°.8$;
$t = 81°$ F.; $n = 0.9$.

Per cent. of cane-sugar, 95.83.

32. Sugar from St. Jago de Cuba—Received from the custom-house, Boston, and thus labelled: "Sample of 133 boxes 'second quality' brown sugar, imported into Boston, from St. Jago de Cuba, in the brig General Brooks, by John S. Hill, August 12, 1845; duty 2½ cents per pound."

A yellowish white, dry sugar, having a good grain, but not a crystalline appearance.

$e = 0.25$; $a = 40°.2$;
$d = 1.1007$; $a'' = 12°.6$;
$t = 60°.9$ F.; $n = 0.9$.

Per cent. of cane sugar, 95.48.

33. Sugar from Trinidad—Received from the custom-house, Boston, and thus labelled: "Sample of 149 boxes brown sugar, imported into Boston, from Trinidad, in the barque Franklin, by Benjamin Burgess & Sons, October 18, 1845; duty 2½ cents per pound."

A brownish yellow, rather dry sugar, having a good grain and a dull uncrystalline appearance.

$e = 0.25$; $a = 41°.1$;
$d = 1.1067$; $a'' = -12$;
$t = 80°$ F.; $n = 0.9$.

Per cent. of cane sugar, 94.89.

34. Sugar from Trinidad—Received from the custom-house, Boston, and thus labelled: "Sample of 100 boxes brown sugar, imported into Boston, from Trinidad, in the barque Franklin, by Benjamin Burgess & Sons, October 11, 1845; duty 2¼ cents per pound."

A light colored, dry, clayed sugar, having a good grain.

$e = 0.25$; $a = 39.4$;
$d = 1.1135$; $a'' = -13°.32$;
$t = 66°.3$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.94.

35. Sugar from Trinidad.—Received from the custom-house, Boston, and thus labelled: "Sample of 72 boxes brown sugar, imported into Boston, from Trinidad, in the barque Smyrna, by Philo S. Shelton, September 30, 1845; duty 2½ cents per pound.

A yellowish gray, dry sugar, having a good grain and an uncrystalline appearance.

$e = 0.25$; $a = 30°.4$;
$d = 1.1018$; $a'' = -12°$;
$t = 80°$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.34.

36. Sugar from Matanzas.—Received from the custom-house, Philadelphia, and marked "Sample of 550 boxes sugar from Matanzas, in the brig Balize, Captain Searles, consigned to Borie & McKean, marked [B;] October 1, 1845."

A brownish white, dry sugar, having a good grain, and gritty; very hard lumps occurring in it.

$e = 0.25$; $a = 41°$;
$d = 1.1034$; $a'' = 12$;
$t = 83°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 95.06.

37. Sugar from Mayaguez.—Received from the custom-house, Philadelphia, and marked "Sample of sugar from Mayaguez, per schooner Nonpareil, Captain Homer, consigned to Mason & Kirkland, marked P; 60 hhds."

A light colored (nearly white) moist sugar, having a rather inferior grain, and a pasty feeling between the fingers.

$e = 0.25$; $a = 39°.1$;
$d = 1.1021$; $a'' = 11°.7$;
$t = 80°$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.23.

38. Sugar from Cienfuegos.—Received from the custom-house, Boston, and thus labelled: "Sample of 194 boxes brown sugar, imported into Boston from Cienfuegos, in the brig Eliza Burgess, by Benj. Burgess & Sons, August 25, 1845. Duty 2½ cents. per lb."

A light yellow, dry sugar, having a very good hard grain, and a crystalline appearance.

$e = 0.25$; $a = 39°.9$;
$d = 1.1017$; $a'' = -12°.2$;
$t = 79°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.64.

39. Sugar from Mansanilla.—Received from the custom-house, Boston, and thus labelled: "Sample of 83 boxes brown sugar, imported into Boston from Mansanilla, in the brig Nerews, by Homer & Sprague, October 6, 1845. Duty 2½ cents per lb."

A yellowish white, dry sugar, having an excellent crystalline grain.

$e = 0.25$; $a = 40°.96$;
$d = 1.1062$; $a'' = -13$;
$t = 63°.3$ F.; $n = 0.9$.

Per cent. of cane sugar, 96.72.

40. Sugar from Bahia.—Received from the custom-house, Philadelphia, and marked "Samples of sugar in cases, per the schooner Almira, from Bahia, Captain Norgram, consigned to S. A. Lewis & Brothers, September 15, 1845."

A grayish white, slightly moist sugar, having only a tolerable grain; large, but not very hard lumps occurring.

$e = 0.25$; $a = 41°.1$;
$d = 1.103$; $a'' = -11°.9$;
$t = 82°$; $n = 0.9$.

Per cent. of cane sugar, 95.08.

*Quebrado 3a.*

41. Sugar from Havana.—Received from the custom-house, New York, and marked "Ship Adelaide, Adams, master, from Havana; arrived September 15, 1845; marked AK; 82 boxes brown sugar, imported by Spofford, Tileston & Co. Duty 2½ cents per pound."

A dull yellow, dry sugar, having a good grain; small hard lumps occurring.

$e = 0.25$; $a = 36°.3$;
$d = 1.095$; $a'' = 12°.5$;
$t = 54°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 87.91.

42. Sugar from St. Jago de Cuba.—Received from the custom-house, Boston, and labelled thus: "Sample of 31 bbls. brown sugar, imported into Boston from St. Jago de Cuba, in the brig General Brooks, by John S. Hill, August 12, 1845. Duty 2½ cents per lb."

A brownish yellow, dry sugar, having a good grain and a dull uncrystalline appearance.

$e = 0.25$; $a = 38°.9$;
$d = 1.10835$; $a'' = -12.3$;
$t = 61°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.62.

43. Sugar from Trinidad.—Received from the custom-house, Philadelphia, and marked "Brown sugar, in boxes, from Trinidad, per schooner Fashion, Howard, master, marked R. V.; consigned to S. & W. Welsh; August 25, 1845."

It contains numerous small dark dry lumps, which crumble readily between the teeth, though not between the fingers; and these are mixed with fine powdered sugar, of a lighter color.

$e = 0.25$; $a = 39°.1$;
$d = 1.100$; $a'' = -13°$;
$t = 26°.5$ C.; $n = 0.9$.

Per cent. of cane sugar, 93.38.

44. Sugar from Trinidad.—Received from the custom-house, Philadelphia, and marked "Sample of brown sugars, in boxes, from Trinidad, per schooner Fashion, Howard, master, marked V; consigned to S. & W. Welsh; August 25, 1845."

A brownish yellow, dry sugar; strong grain.

$e = 0.25$, $a = 38°.8$;
$d = 1.1011$; $a'' = -11°.2$;
$t = 75°$ F.; $n = 0.9$.

Per cent. of cane sugar, 89.85.

45. Sugar from Trinidad.—Received from the custom-house, Philadelphia, and marked "Sample of brown sugar, in boxes, from Trinidad, per schooner Fashion, Howard, master, marked L; consigned to S. and W. Welsh; August 25, 1845."

A brownish yellow sugar, of rather hard grain; small lumps occurring in it of still stronger grain.

$e = 0.25$; $a = 38°.7$;
$d = 1.100$; $a'' = -11°$;
$t = 79°$ F.; $n = 0.9$.

Per cent. of cane sugar, 89.37.

46. Sugar from Trinidad.—Received from the custom-house, Philadelphia, and marked "Sample of brown sugar, in boxes, from Trinidad, per schooner Fashion, Howard, master, marked H; consigned to S. and W. Welsh; August 25, 1845."

A deep brownish yellow, slightly moist sugar, having only a tolerable grain; large lumps of a darker color occurring in it frequently.

$e = 0.25$; $a = 38°$;
$d = 1.096$; $a'' = -10°.5$;
$t = 85°$ F.; $n = 0.9$.

Per cent. of cane sugar, 87.47.

47. Sugar from Trinidad.—Received from the custom-house, Philadelphia, and marked "Sample of brown sugar, in boxes, from Trinidad, per schooner Fashion, Howard, master, marked D S; consigned to S. and W. Welsh; August 25, 1845."

Deep brownish yellow, and dry; fair; grain rather gritty between the fingers; lumps of a darker color occurring.

$e = 0.25$; $a = 39°$;
$d = 1.0898$; $a'' = -11°.2$;
$t = 85°$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.11.

48. Sugar from Trinidad.—Received from the custom-house, Boston, and labelled as follows: "Sample of 28 boxes brown sugar, imported into Boston, from Trinidad, in the barque Franklin, by Gossler & Co., October 11, 1845. Duty 2½ cents per lb."

A brownish yellow, rather dry sugar, having a good grain.

$e = 0.25$; $a = 39°.5$;
$d = 1.1025$; $a'' = -11°.8$;
$t = 67°.7$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.16.

49. Sugar from Trinidad.—Received from the custom-house, Boston, and labelled as follows: "Sample of 150 boxes brown sugar, imported into Boston, from Trinidad, in the barque Franklin, by Benjamin Burgess & Sons, October 11, 1845. Duty 2½ cents per lb."

A reddish brown, dry sugar, having a good grain, with a dull uncrystalline appearance.

$e = 0.25$; $a = 38°.5$;
$d = 1.1043$; $a'' = -12°.6$;
$t = 64°$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.81.

50. Sugar from Nuevitas.—Received from the custom-house, New York, and marked "Brig Demarara, Blanchard, master, from Nuevitas; arrived September 22, 1845. F E, 481 bbls. brown sugar, imported by Holt & Owen. Duty 2½ cents per lb."

A deep yellow, and slightly moist; tolerable grain.

$e = 0.25$; $a = 38°.5$;
$d = 1.1007$; $a'' = -11°$;
$t =$ $n = 0.9$.

Per cent. of cane sugar, 88.89.

51. Sugar from Nuevitas.—Received from the custom-house, New York, and marked "Brig Demarara, Blanchard, master, from Nuevitas; arrived September 22, 1845. F E, 78 boxes brown sugar, imported by Holt & Owen. Duty 2½ cents per lb."

A dry, yellow sugar, having a good grain.

$e = 0.25$; $a = 39°.9$;
$d = 1.102$; $a'' = -11°.2$;
$t = 78°$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.69.

52. Sugar from Nuevitas.—Received from the custom-house, New York, and thus labelled: "Brig Amanda, from Nuevitas, arrived September 26, 1845. S V, 200 boxes brown sugar, imported by Holt & Owen. Duty 2½ cents per lb."

A dull yellow, moist sugar, having a very inferior grain, and a dull uncrystalline appearance; pasty between the fingers.

$e = 0.25$; $a = 35°.9$;
$d = 1.100$; $a'' = -10°.8$;
$t = 55°.2$; $n = 0.9$.

Per cent. of cane sugar, 84.

53. Sugar from Manilla.—Received from the custom-house, New York, and marked "Ship Delhi, Williams, master, from Manilla; arrived August 14, 1845; no mark; 8,371 bags brown sugar, imported by Tucker & Doland. Duty 2½ cents per lb."

A dry, brown colored sugar, of a hard grain and peculiar flavor; lumps of a darker color, and harder grain, occurring frequently.

$e = 0.25$; $a = 39°.5$;
$d = 1.1027$; $a'' = -11°.6$;
$t = 74°.8$; $n = 0.9$.

Per cent. of cane sugar, 91.66.

MUSCOVADO SUGARS.

54. Sugar from Havana.—Received from the custom-house, New York, and marked "Ship Adelaide, Adams, master, from Havana; arrived September 15, 1845. S G, 7 hhds. brown sugar, imported by Spofford, Tileston & Co. Duty 2½ cents per pound."

A very deep yellow, moist sugar, of a rather inferior grain; pasty between the fingers.

$e = 0.25$; $a = 37°.3$;
$d = 1.0997$; $a'' = -10°.2$;
$t = 77°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 85.35.

*Muscovado sugar from St. Jago de Cuba.*

55. Received from the custom-house, Philadelphia, and marked "Brown sugar, in hhds., per brig Mary Helen; West, master, from St. Jago de Cuba, consigned to Robert Adams & Co., and marked W. C. September 12, 1845."

A delicate flavored raw sugar; aroma, fresh and full; grain fine, and rather soft; also somewhat moist.

$e = 0.25$; $a = 41°$;
$d = 1.1022$; $a'' = -11°.6$;
$t = 23°.5$ C. $n = 0.9$.

Per cent. of cane sugar, 94.37.

56. Received from the Philadelphia custom-house, and marked "Sample of sugar in hhds. from St. Jago de Cuba, per brig Vulture, Mayo, master, marked *V*, and consigned to Burling & Dixon, August 28, 1845."

A dark brown, very moist, soft weak grained sugar.

$e = 0.25$; $a = 38°.8$;
$d = 1.0965$; $a'' = -12°.2$;
$t = 25°.6$ C.; $n = 0.9$.

Per cent. of cane sugar, 92.18.

57. Received from the Philadelphia custom-house, and marked "Sample of brown sugar in hhds., per brig Mary Helen, West, master, from St. Jago de Cuba. consigned to Robert Adams & Co., marked *A*.; September 12, 1845."

A brownish yellow, moist sugar; grain rather hard; contains lumps of a hard strong grain.

$e = 0.25$; $a = 38°.1$;
$d = 1.10075$; $a'' = -11°$;
$t = 75°$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.23.

58. Received from the New York custom-house, and marked "Imported in schooner Charran, from St. Jago de Cuba, October

9, 1845, by Jonathan Thompson, jr., 18 hhds. brown sugar, marked TT; duty 2½ cents per pound."

A yellowish white, moist sugar, of an inferior grain; pasty between the fingers; a few lumps of good grain occurring in it.

$e = 0.25$; $a = 37°.5$;
$d = 1.1022$; $a'' = -11°.6$;
$t = 77°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.28.

59. Received from the New York custom-house, and marked "Imported in brig E. D'Wolfe, Steelman, master, from St. Jago de Cuba, by Dunscomb & Beckwith, August 27, 1845, 29 hhds. brown sugar, marked *W. C.*"

A dull yellowish white, moist sugar, having a tolerable grain.

$e = 0.25$; $a = 38°.6$;
$d = 1.1016$; $a'' = -11°.4$;
$t = 79°$ F. $n = 0.9$.

Per cent. of cane sugar, 89.79.

60. Received from the New York custom-house, and marked "Imported in brig E. D'Wolfe, from St. Jago de Cuba, by Dunscomb & Beckwith, August 27, 1845, 50 hhds, brown sugar, marked $\frac{RW}{E}$."

A deep yellow, moist sugar, of a dull appearance, and having a very inferior grain.

$e = 0.25$; $a = 35°5$;
$d = 1.1042$; $a'' = -12°$;
$t = 63°$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.30.

61. Received from the custom-house, New York, marked "Imported in brig E. D'Wolfe, from St. Jago de Cuba, by Dunscomb & Beckwith, August 27, 1845, 98 hhds. brown sugar, marked $\frac{RW}{S}$."

A yellow, moist sugar, having a rather inferior grain, and dull appearance.

$e = 0\ 25$; $a = 40°$;
$d = 1.1077$; $a'' = -13.2$.
$t = 60°.1$ F.; $n = 0.9$.

Per cent. of cane sugar, 95.26.

62. Received from the New York custom-house, and marked "Imported in brig E. D'Wolfe, Steelman, master, from St. Jago de Cuba, by Dunscombe & Beckwith, August 27, 1845, $\frac{RW}{S}$ 4 bbls. sugar; duty 2½ cents per pound."

A yellow, moist sugar, of a rather inferior grain and dull appearance.

$e = 0.25$; $a = 37°.4$;
$d = 1.1009$; $a'' = -11°.4$;
$t = 74°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 87.79.

63. Received from the Boston custom-house, and marked "Sample of 179 boxes clayed sugar, imported into Boston, from St. Jago de Cuba, in the brig John H. Stephens, by Chamberlain & Co., September 30, 1845; duty 2½ cents per pound."

A dark yellow, rather dry sugar, having a good grain; rather mealy when rubbed between the fingers.

$e = 0.25$; $a = 40°.1$;
$d = 1.1075$; $a'' = -12°.1$;
$t = 60°$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.98.

64. Received from the Boston custom-house, and marked "Sample of 40 hhds. muscovado sugar, imported into Boston, from St. Jago de Cuba, in the brig General Brooks, by John S. Hill, August 12, 1845; duty 2½ cents per pound."

A light yellow, moist sugar, of a tolerable grain and rather bright crystalline appearance.

$e = 0.25$; $a = 38°.3$;
$d = 1.1018$; $a'' = -11°.3$;
$t = 77°$ F.; $n = 0.9$.

Per cent. of cane sugar, 89.06.

65. Received from the custom-house, Boston, marked "Sample of 18 hogsheads muscovado sugar, imported into Boston from St. Jago de Cuba, in the brig Jno. H. Stephens, by Chamberlain & Co., September 30, 1845; duty 2½ cents per pound."

A dark brownish yellow, and very moist sugar, having a rather inferior grain, (pasty between the fingers,) and a peculiar odor.

$e = 0.25$; $a = 37°.4$;
$d = 1.1037$; $a'' = -11°.9$;
$t = 63°$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.47.

66. Sugar from Trinidad.—Received from the Philadelphia custom-house, and marked "Sample of brown sugar in boxes, from Trinidad, per schooner Fashion, Howard, master; marked R. Consigned to S. and W. Welsh. August 25, 1845."

A yellow sugar; grain rather strong.

$e = 0.25$; $a = 38°.2$;
$d = 1.1012$; $a'' = -11°$;
$t = 79°$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.59.

67. Sugar from Trinidad.—Received from the custom-house, Boston, and marked "Sample of 35 boxes brown sugar, imported into Boston from Trinidad, in the brig Smyrna, by Philo S. Shelton, September 30, 1845; duty 2½ cents per pound."

A dark brown, moist sugar, of rather inferior grain and dull appearance. Resembles very much a well dried sediment.

$e = 0.25$; $a = 38°.5$;
$d = 1.1020$; $a'' = -11°.7$;
$t = 80°$ F.; $n = 0.9$.

Per cent. of cane sugar, 90.

68. Sugar from Nuevitas.—Received from the New York custom-house, and marked "Brig Demarara, Blanchard, master, from Nuevitas; arrived September 22, 1845. J L C, 35 hhds. brown sugar, imported by Holt & Owen."

A light yellow and slightly moist sugar, of fair grain.

$e = 0.25$; $a = 40°.9$;
$d = 1\ 1039$; $a'' = -12°$;
$t = 81°$ F.; $n = 0.9$.

Per cent. of cane sugar, 94.9.

*Muscovado sugar from St. Croix.*

69. Received from the custom-house, New York, marked "Schr. Empire, from St. Croix, imported by B. DeForest & Co.; 120 hogsheads sugar (brown;) arrived September 22, 1845. Duty 2½ cents per pound."

A moist, light yellow sugar, having a tolerable grain.

$e = 0.25$; $a = 40°$;
$d = 1.1028$; $a'' = -11°.7$;
$t = 77°.7$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.75.

70. Received from the New York custom-house, and marked "Brig Star, Hubbard, master, from St. Croix; arrived September 1, 1845; 108 hogsheads brown sugar, imported by B. DeForest & Co. Duty 2½ cents per pound."

A light yellow and slightly moist sugar; good grain, and crystals well defined, but not large.

$e = 0.25$; $a = 40°.6$;
$d = 1.1028$; $a'' = -11°.4$;
$t = 83°$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.22.

71. Received from the New York custom-house, and marked "Imported in brig Hyder Ali, from St. Croix, September 11, 1845, by Alsop & Chauncey, 12 hogsheads brown sugar, marked B G. Duty 2½ cents per pound."

A light yellow and slightly moist sugar; grain good.

$e = 0.25$; $a = 40°.2$;
$d = 1.1033$; $a'' = -11°.5$;
$t = 82°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.72.

72. Received from the custom-house, New York, marked "Imported in the barque Isabella, from St. Croix, September 4, 1845, by Alsop & Chauncey, 10 hogsheads brown sugar, marked P. Duty 2½ cents per pound."

A dull yellow sugar, with a tolerable grain, and slightly moist; crystals of a rather small size.

$e = 0.25$; $a = 38°.95$;
$d = 1.1023$; $a'' = -12°.9$;
$t = 71°$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.33.

73. Received from the custom-house, New York, marked "Imported in the brig Hyder Ali, from St. Croix, September 11, 1845, by Beasly & McCready, 74 hogsheads brown sugar, marked F. Duty 2½ cents per pound."

A light yellow, moist sugar, with a rather good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 39°.4$;
$d = 1.1045$; $a'' = -13°.5$;
$t = 60°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 95.14.

74. Received from the custom-house, New York, and marked "Imported in brig Hyder Ali, from St. Croix, September 11, 1845, by Alsop & Chauncey, 25 hhds. brown sugar, marked [D. D. L.] Duty 2½ cents per pound."

A light yellow, moist sugar, with quite a good grain, and having a bright crystalline appearance.

$e = 0.25$; $a = 40°.4$;
$d = 1.1047$; $a'' = -13°.2$;
$t = 61°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 96.20.

75. Received from the New York custom-house, and marked "Imported in schooner Abisha Jenkins, Haines, master, from St.

Croix, September 5, 1845, by Aymar & Co., 71 hhds. brown sugar, marked R. I. G. Duty 2½ cents per pound."

A dull yellow sugar; grain inferior; a sort of pasty and mealy feeling between the fingers.

$e = 0.25$; $a = 39°.9$;
$d = 1.1027$; $a'' = -11°.4$;
$t = 77°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.95.

76. Received from the New York custom-house, and marked "Brig Eliza, from St. Croix, arrived August 30, 1845; 198 hhds. brown sugar, imported by Benj. De Forest & Co. Duty 2½ cents per pound."

A light yellow, moist sugar; grain tolerable; rather bright crystalline appearance.

$e = 0.25$; $a = 41°.4$;
$d = 1.10625$; $a'' = -12°.5$;
$t = 83°$ F.; $n = 0.9$.

Per cent. of cane sugar, 96.15.

77. Received from the New York custom-house, and marked "Imported in barque Isabella, from St. Croix, September 4, 1845, by Alsop & Chauncey, 10 hhds brown sugar, marked H. Duty 2½ cents per pound."

A light yellow, moist sugar, very light colored for Muscovado; having a rather inferior grain, and a dull appearance; crystals very small.

$e = 0.25$; $a = 40°.2$;
$d = 1.1034$; $a'' = -12°.9$;
$t = 71°.4$; $n = 0.9$.

Per cent. of cane sugar, 95.40.

78. Received from the New York custom-house, and marked "Barque Rosalie, from St. Croix, arrived September 3, 1845; 18 hogsheads brown sugar, imported by J. C. Whitmore. Duty 2½ cents per pound."

A light yellow, moist sugar, of good grain, and having a bright crystalline appearance.

$e = 0.25$; $a = 40°.3$;
$d = 1.1054$; $a'' = -11°.8$;
$t = 76°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.28.

79. Received from the custom-house, New York, and marked

"Imported in schooner Abisha Jenkins, from St. Croix, September 5, 1845, by Aymar & Co., 22 hogsheads brown sugar, marked W. Duty 2½ cents per pound."

A light yellow, moist sugar, having a good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 40°.4$;
$d = 1.1043$; $a'' = -12°$;
$t = 61°.7$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.94.

80. Received from the New York custom-house, and marked "Imported in schooner Abisha Jenkins, from St. Croix, by Aymar & Co., 23 hogsheads brown sugar, marked G. S. H. Duty 2½ cents per pound."

A very light colored, moist sugar; grain rather inferior; dull uncrystalline appearance.

$e = 0.25$; $a = 39°$;
$d = 1.1035$; $a'' = -12°.3$;
$t = 82°$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.14.

81. Received from the New York custom-house, and marked "Imported in schooner Abisha Jenkins, from St. Croix, September 5, 1845, by Aymar & Co., 30 hhds. brown sugar, marked W. N. R. Duty 2⅛ cents per lb."

A light yellow, moist sugar, having a very good grain, and bright crystalline appearance.

$e = 0.25$; $a = 40°.6$;
$d = 1.10475$; $a'' = -12°.1$;
$t = 83°$ F.; $n = 0.9$.

Per cent. of cane sugar, 94.41.

82. Received from the New York custom-house, and marked "Imported in brig Elizabeth, from St. Croix, August 11, 1845, by Ezra Whitmore, 26 bbls. sugar, marked D & C. Duty 2½ cents per lb."

A very light yellow, moist sugar, having a good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 41°.2$;
$d = 1.1057$; $a'' = -12°.7$;
$t = 80°$ F.; $n = 0.9$.

Per cent. of cane sugar, 96.30.

83. Received from New York custom-house, and marked "Im-

ported in schooner Abisha Jenkins, from St. Croix, September 5, 1845, by Aymar & Co., 10 hhds. brown sugar, marked C.V. Duty 2½ cents per lb."

A light yellow and very moist sugar; grain rather poor, and inferior.

$e = 0.25$; $a = 39°.2$;
$d = 1.1004$; $a'' = -11°.5$;
$t = 81°$ F.; $n = 0.9$.

Per cent. of cane sugar 91.24.

84. Received from the New York custom-house, and marked "Imported in brig Hyder Ali, from St. Croix, September 11, 1845, by Alsop & Chauncey, 40 hhds, brown sugar, marked MS. Duty 2½ cents per lb."

A light yellow, moist sugar, having a rather good grain and a bright crystalline appearance.

$e = 0.25$; $a = 39°.75$;
$d = 1.1035$; $a'' = -11°.75$;
$t = 80°$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.38.

85. Received from the custom-house, New York, marked "Imported in schooner Abisha Jenkins, from St. Croix, September 5, 1845, by Aymar & Co., 19 hhds. brown sugar, marked H. Duty 2½ cents per lb."

A light yellow and quite moist sugar, having a good grain and bright crystalline appearance.

$e = 0.25$; $a = 39°.6$;
$d = 1.1033$; $a'' = -12°$;
$t = 66°.3$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.65.

86. Received from the New York custom-house, and marked "Imported in barque Isabella, from St. Croix, September 4, 1845, by Alsop & Chauncey, 15 hhds brown sugar, marked HP. Duty 2½ cents per lb."

A very light colored, moist sugar, having a good grain and a very bright crystalline appearance.

$e = 0.25$; $a = 40°.6$;
$d = 1.1031$; $a'' = -12°$;
$t = 76°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 94.36.

87. Received from the custom-house, New York, marked "Im-

ported in brig Elizabeth, from St. Croix, August 11, 1845, by Ezra Whitmore, 13 hhds. sugar, marked AL. Duty 2½ cents per lb."

A light yellow, moist sugar, having a good grain and a bright crystalline appearance; had lumps occurring throughout.

$e = 0.25$; $a = 39.$;
$d = 1.1025$; $a'' = -12°.6$;
$t = 66°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.83.

88. Received from the custom-house, New York, marked "Imported in the schooner Abisha Jenkins, from St. Croix, September 5, 1845, by Aymar & Co., 5 hhds. brown sugar, marked H A W. Duty 2½ cents per lb."

A light yellow, moist sugar, having a good grain and a bright crystalline appearance.

$e = 0.25$; $a = 41°.4$;
$d = 1.1048$; $a'' = -12°.1$;
$t = 76°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 95.82.

*Muscovado sugar from Porto Rico.*

89. Received from the Philadelphia custom-house. A light colored and rather moist sugar.

$e = 0.25$ $a = 39°.5$;
$d = 1.1007$; $a'' = -12°.1$;
$t = 18°$ C.; $n = 0.9$.

Per cent. of cane sugar, 92.79.

90. Received from the Philadelphia custom-house. A moist yellow sugar, having a rather good grain; interspersed with lumps of a darker color.

$e = 0.25$; $a = 38°$;
$d = 1.0964$; $a'' = -10°.9$;
$t = 27°$ C.; $n = 0.9$.

Per cent. of cane sugar, 88.27.

91. Received from the custom-house, Philadelphia. A moist yellow sugar, of good grain.

$e = 0.25$; $a = 38°.7$;
$d = 1.0985$; $a'' = -10°.9$;
$t = 19°$ C.; $n = 0.9$.

Per cent. of cane sugar, 89.33.

92. Received from the Philadelphia custom-house. A very light colored, moist sugar, having a fine grain.

$e = 0.25$; $a = 39°.3$;
$d = 1.0988$; $a'' = -12°.2$;
$t = 19°$ C.; $n = 0.9$.

Per cent. of sugar cane, 92.84.

93. Received from the custom-house, New York, marked "Imported in brig Aldrich, from Porto Rico, September 2, 1845, by Chastelain & Ponvert 95 hhds. sugar; permitted without mark; 25 having no mark, and 70 marked HP; duty 2½ cents per pound."

A dingy yellow, moist sugar, having a tolerable grain, and a rather bright crystalline appearance.

$e = 0.25$; $a = 39°.85$;
$d = 1.1023$; $a'' = -11°.75$;
$t = 76°$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.69.

94. Received from the custom-house, New York, marked "Imported in the brig Aldrich, from Porto Rico, by Chastelain & Ponvert, 7 hhds brown sugar; permitted without mark; duty 2½ cents per pound."

A deep yellow, moist sugar, having a tolerable grain and crystalline appearance.

$e = 0.25$; $a = 40°.9$;
$d = 1.1052$; $a'' = -12°.9$;
$t = 65°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 96.45.

95. Received from the custom-house, New York, and marked "Imported in brig Aldrich, from Porto Rico, by Benjamin De Forest & Co., 17 hhds. brown sugar, marked HC. August 29, 1845. Duty 2½ cents per pound."

A dull, grayish yellow, moist sugar, having an inferior grain.

$e = 0.25$; $a = 38°.7$;
$d = 1.1042$; $a'' = -11°.2$;
$t = 76°$ F.; $n = 0.9$.

Per cent. of cane sugar, 89.46.

96. Received from the custom-house, New York, marked "Imported in brig Aldrich, from Porto Rico, September 2, 1845, by Chastelain & Ponvert, 95 hhds. brown sugar; permitted without mark; 75 were marked HP; duty 2½ cents per pound."

A dingy yellow sugar, having a rather good grain and crystalline appearance.

$e = 0.25$; $a = 37°$;
$d = 1.1006$; $a'' = -10°.35$;
$t = 66°$ F.; $n = 0.9$.

Per cent. of cane sugar, 85.05.

*Muscovado sugar from Ponce, Porto Rico.*

97. Received from the Philadelphia custom-house, and marked "Brown sugar, in hhds., per schooner Caroline, from Ponce, P. R. Consigned to John Latour & Co.; marked S A. September 2, 1845.

Color light brown; flavor delicate; grain most, but strong.

$e = 0.25$; $a = 40°$;
$d = 1.1008$; $a'' = -12°$;
$t = 23°$ C.; $n = 0.9$.

Per cent. of cane sugar, 93.48.

98. Received from the Philadelphia custom-house, marked "Sample of brown sugar, in hhds., per the schooner Caroline, from Ponce, P. R. Consigned to John Latour & Co.; marked Q. September 2, 1845."

A light yellow, moist, strong grained sugar.

$e = 0.25$; $a = 39°.8$;
$d = 1\ 101$; $a'' = -13°.2$;
$t = 26°$ C.; $n = 0.9$.

Per cent. of cane sugar, 95.46.

99. Received from the Philadelphia custom-house marked "Sample of sugar in hhds., per brig Sidney, from Ponce, P. R. Consigned to Soutter & Broughton; mark, F. S. September 10, 1845."

A moist, brownish yellow, strong grained sugar; gritty between the fingers.

$e = 0.25$; $a = 40°.1$;
$d = 1.1024$; $a'' = -11°.4$;
$t = 75°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.43.

100. Received from the Philadelphia custom-house, marked "Sample of sugar, in hhds, per the brig Sidney, from Ponce, P. R. Consigned to Soutter & Broughton; mark '*Puente Bajoza*' Z. September 10, 1845."

A moist, brownish yellow, strong grained sugar.

$e = 0.35$; $a = 38°.1$;
$d = 1.0981$; $a'' = -10°.4$;
$t = 75°$ F.; $n = 0.9$.

Per cent. of cane sugar, 87.27.

101. Received from the Philadelphia custom-house, and marked "Sample of brown sugar, in hhds., per the schooner Caroline, from Ponce, P. R. Consigned to John Latour & Co.; marked V. September 2, 1845."

A moist, light brown sugar, having a good grain.

$e = 0.25$; $a = 38°.9$;
$d = 1.1006$; $a'' = -11°.2$;
$t = 75°.7$ F.; $n = 0.9$

Per cent. of cane sugar, 90.03.

102. Received from the Philadelphia custom-house, and marked "Sample of sugar, in hhds., per the brig Sidney, Ponce, P. R. Consigned to Soutter & Broughton; mark, C. September 10, 1845."

A brownish yellow, moist sugar, having a tolerable grain.

$e = 0.25$; $a = 38°.7$;
$d = 1.0997$; $a'' = -10°.8$;
$t = 77°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.95.

103. Received from the Philadelphia custom-house, and marked "Sample of brown sugar, in hhds., per schooner Caroline, from Ponce, P. H. Consigned to John Latour & Co.; marked '*A. L. Quemado.*' September 2, 1845."

A light brown, moist sugar; grain good; gritty between the fingers.

$e = 0.25$; $a = 39°$;
$d = 1.0982$; $a'' = -11°$;
$t = 78°$ F.; $n = 0.9$.

Per cent. of cane sugar, 90.

104. Received from the New York custom-house, and marked "Imported in brig Overman, from Ponce, P. R., August 16, 1845, by P. Harmony & Co., 35 hhds. sugar, marked [Quemado, A. L.] Duty 2½ cents per pound."

A light yellow, slightly moist sugar; grain good.

$e = 0.25$; $a = 40°$;
$d = 1.1023$; $a'' = -11°.2$;
$t = 79°$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.85.

105. Received from the New York custom-house, and marked, "Imported in brig L'Orient, from Ponce, P. R., September 5, 1845, by Howland & Aspinwal, 48 hhds. brown sugar, marked *Silvester Solas, Ponce, P. R.* Duty 2½ cents per pound."

A light yellow, quite dry sugar; grain good.

$e = 0.25$; $a = 41°$;
$d = 1.1035$; $a'' = -11°.3$;
$t = 82°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.70.

106. Received from the New York custom-house, marked "Imported in brig Overman, from Ponce, P. R, August 16, 1845, by P. Harmony, Nephews & Co., 17 hhds. sugar, marked M. P. R. Duty 2½ cents per pound."

A light yellow, moist sugar; grain rather good.

$e = 0.25$; $a = 38°.4$;
$d = 1.101$; $a'' = -10°.7$;
$t = 77°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.31.

107. Received from the custom-house, New York, marked "Imported in the brig L'Orient, from Ponce, P. R. September 5, 1845, by H. Southmayd & Son, 85 hhds. brown sugar, marked *Fortuna*. Duty 2½ cents per pound."

A yellow-colored, moist sugar, with a tolerable grain.

$e = 0.25$; $a = 40°.65$;
$d = 1.1054$; $a'' = -12°.55$;
$t = 62°.7$ F.; $n = 0.9$.

Per cent. of cane sugar, 95.37.

108. Received from the custom-house, New York, marked "Imported in the brig L'Orient, from Ponce, P. R., September 5, 1845, by Howland & Aspinwal, 70 hhds. brown sugar, marked E. Duty 2½ cents per pound."

A light-yellow, moist sugar, having only a tolerable grain, and a rather bright crystalline appearance.

$e = 0.25$; $a = 38°$;
$d = 1.1037$; $a'' = -12°.68$.
$t = 62°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.1.

109. Received from the New York custom-house and marked 'Imported in brig L'Orient, from Ponce, P. R., September 5,

1845, by Howland & Aspinwal, 17 hhds. brown sugar, marked M. Y. G. Duty 2½ cents per lb."

A light yellow, moist sugar; grain rather inferior, and appearance dull.

$e = 0.25$; $a = 39°.6$;
$d = 1.103$; $a'' = -11°.7$;
$t = 81°.5$ F. $n = 0.9$.

Per cent. of cane sugar, 92.

110. Received from the custom-house, New York, and marked "Imported in brig Overman, from Ponce, P. R., August 26, 1845, by P. Harmony & Co., 14 hhds., marked *Perseverancia, L. C.* Duty 2½ cents per lb."

A light dull yellow, moist sugar, having only a tolerable grain, and rather crystalline appearance.

$e = 0.25$; $a = 40°$;
$d = 1.1071$; $a'' = -12°.1$;
$t = 62°$ F.; $n = 0.8$.

Per cent. of cane sugar, 93.18.

111. Received from the custom-house, Baltimore, and marked "Schooner Hope, Ponce, P. R., September 3, 1845; 17 hhds., B.; to Withington & Eastman."

A dingy yellow, moist sugar, having a good grain, and a crystalline appearance.

$e = 0.25$; $a = 39°$;
$d = 1.1021$; $a'' = -12°.4$;
$t = 65°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.43.

112. Received from the custom-house, Baltimore, and marked "Schooner Wm. Allen, Ponce; 13 hhds., '*Isabella;*' to Kirkland, Chase & Co. September 24, 1845."

A yellow, moist sugar, having a rather good grain, and a crystalline appearance.

$e = 0.25$; $a = 38°.7$;
$d = 1.1089$; $a'' = -11°.3$;
$t = 67°$. F.; $n = 0.9$;

Per cent. of cane sugar, 89.19.

113. Received from the custom-house, Baltimore, and marked "Schooner Hope, Ponce, P. R., September 3, 1845; 16 bbls., P. M.; to Withington & Eastman."

A deep yellow, moist sugar, having a good grain, and a rather crystalline appearance.

$e = 0.25$; $a = 36°.7$;
$d = 1.101$; $a'' = -11°.4$;
$t = 58°.9$ F.; $n = 0.9$.

Per cent. of cane sugar, 86.54.

114. Received from the custom-house, Baltimore, and marked "Schooner Hope, Ponce, P. R., September 3, 1845; 34 hhds., J. H. C.; to Withington & Eastman."

A light yellow, moist sugar, having a good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 36°.8$;
$d = 1.1012$; $a'' = -11.15$;
$t = 58°$ F.; $n = 0.9$.

Per cent. of cane sugar, 86.26.

*Muscovado sugar from Mayaguez, P. R.*

115. Received from the Philadelphia custom-house, and marked "Sample of sugar from Mayaguez, per schooner Nonpareil, Captain Homer. Consigned to Mason & Kirkland. Marked G., 11 hogsheads.

A yellow, moist sugar, of a good grain; gritty between the fingers.

$e = 0.25$; $a = 40°.7$;
$d = 1.100$; $a'' = -11°$;
$t = 82°$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.85.

116. Received from the custom-house, New York, and marked "Imported in brig Port Leon, from Mayaguez, P. R., September 22, 1845, by J. W. Cudbert, 5 hhds. of sugar, marked B. Duty 2½ cents per pound."

A moist, light yellow sugar, having a rather good grain; tolerably gritty between the fingers.

$e = 0.25$; $a = 40°$;
$d = 1.1006$; $a'' = -11°.3$;
$t = 81°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.15.

117. Received from the custom-house, New York, and marked "Imported in brig Port Leon, from Mayaguez, P. R., September 22, 1845, by J. W. Cudbert, 10 hhds. brown sugar, marked *Rosello*. Duty 2½ cents per lb."

A yellowish white sugar, quite moist, and having a rather inferior grain.

$e = 0.25$; $a = 39°.7$;
$d = 1.1003$; $a'' = -11°.2$;
$t = 82°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.68.

118. Received from the New York custom-house, and marked "Barque Texidor, Clark, master, from Mayaguez, P. R., arrived September 5, 1845; 15[illegible] hhds. brown sugar, imported by Maitland, Comrie & Co.; duty 2½ cents per pound."

A light yellow, slightly moist sugar, of a rather good grain.

$e = 0.25$; $a = 39°.8$;
$d = 1.1031$; $a'' = -11°.25$,
$t = 77°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.52.

119. Received from the custom-house, New York, marked "imported in the schooner Tuscarora, from Mayaguez, P. R., September 8, 1845, by Mason & Thompson, 22 tierces brown sugar, marked A; duty 2½ cents per pound."

A light yellow sugar, of a dull appearance, and having an inferior grain.

$e = 0.25$; $a = 40°.1$;
$d = 1.1044$; $a'' = -12°.34$;
$t = 61°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 94.1.

120. Received from the custom-house, New York, marked "Imported in schooner Tuscarora, from Mayaguez, P. R., September 8, 1845, by Mason & Thompson, 10 hhds. brown sugar, marked *Josefa;* duty 2½ cents per pound."

A little yellow, moist sugar, having a rather good grain and bright crystalline appearance.

$e = 0.25$; $a = 41°$;
$d = 1.1057$; $a'' = -12°.3$;
$t = 60°.8$; $n = 0.9$.

Per cent. of cane sugar, 95.39.

121. Received from the New York custom-house, and marked "Imported in the schooner Tuscarora, from Mayaguez, P. R., September 8, 1845, by Mason & Thompson, 21 hhds. brown sugar, marked C."

A light yellow moist sugar; grain tolerable, and a rather bright crystalline appearance.

$e = 0.25$; $a = 41°.2$;
$d = 1.109$; $a'' = -12°.$;
$t = 79°$ F.; $n = 0.9$.

Per cent. of cane sugar, 94.95.

122. Received from the custom-house, New York, marked "Imported in the schooner Tuscarora, from Mayaguez, P. R., September 8, 1845, by Mason & Thompson, 43 hhds. brown sugar, marked MB; duty 2½ cents per pound."

A rather deep yellow, moist sugar, having only a tolerable grain, and crystalline appearance.

$e = 0.25$; $a = 38°.5$;
$d = 1.1042$; $a'' = -$ [illegible]$°.5$;
$t = 60°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 89.66.

123. Received from the custom-house, Boston, marked "Sample of 88 hhds. brown sugar, imported into Boston, from Mayaguez, in the brig Archelaus, by Crocker & Sturgis, August 28, 1845; duty 2½ cents per pound."

A light yellow, moist sugar, having a tolerable grain, and a rather bright crystalline appearance.

$e = 0.25$; $a = 39°.7$;
$d = 1.10475$; $a'' = -12°.44$;
$t = 64°.3$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.48.

124. Received from the custom-house, Boston, marked "Sample of 132 hhds. brown sugar, imported into Boston from Mayaguez, in the barque Ed. Kippoch, by Robert Bailey, September 4, 1845; duty 2½ cents per pound."

A light yellow, moist sugar, having a tolerable grain, and rather bright crystalline appearance.

$e = 0.25$; $a = 39°.7$;
$d = 1.1042$; $a'' = -12°.33$;
$t = 64°.9$ $n = 0.9$.

Per cent. of cane sugar, 93.36.

125. Received from the Boston custom-house, and marked "Sample of 41 hhds. brown sugar, imported into Boston from Mayaguez, in the brig Archelaus, by Crocker & Sturgis, August 38, 1845; duty 2½ cents per pound."

A yellow, moist sugar, of a tolerable grain; rather bright crystalline appearance.

$e = 0.25$; $a = 38°.7$;
$d = 1.1045$; $a'' = -10°.5$;
$t = 85°$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.

126. Received from the custom-house, Boston, marked "Sample of 9 hhds. of brown sugar, imported into Boston from Mayaguez, in the barque Ed. Kippoch, by Robert Bailey, September 4, 1845; duty 2½ cents per pound."

A light yellow, moist sugar, having a rather good grain, and bright crystalline appearance.

$e = 0.25$; $a = 39°.67$;
$d = 1.1045$; $a'' = -11°.2$;
$t = 64°.9$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.14.

127. Received from the custom-house, Boston, marked "Sample of 24 hhds. brown sugar, imported into Boston from Mayaguez, in the barque Ed. Kippoch, by Robert Bailey, September 4, 1845; duty 2½ cents per pound."

A light yellow, most sugar, having a good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 39°.3$;
$d = 1.103$; $a'' = -11°.2$;
$t = 67°$ F.; $n = 0.9$.

Per cent. of cane sugar, 90.21.

128. Received from the custom-house, Boston, marked "Sample of 53 hhds. brown sugar, imported into Boston from Mayaguez, in the barque Ed. Kippoch, by Robert Bailey, September 4, 1845; duty 2½ cents per pound."

A light yellow, moist sugar, having a good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 40°.48$;
$d = 1.1026$; $a'' = -12°.62$;
$t = 69°.3$ F.; $n = 0.9$.

Per cent. of cane sugar, 95.36.

129. Received from the custom-house, Boston, marked "Sample of 21 hhds. brown sugar, imported into Boston from Mayaguez in the barque Ed. Kippoch, by Robert Bailey, September 4, 1845; duty 2½ cents per pound."

A light yellow, moist sugar, having a rather good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 38°.4$;
$d = 1.0993$; $a'' = -11°$;
$t = 83°$ F.; $n = 0.9$.

Per cent of cane sugar, 88.88.

130. Received from the custom-house, Boston, marked "Sample of 20 hogsheads of brown sugar, imported into Boston from Maya-

guez, in the barque Ed. Kippoch, by Robert Bailey, September 4, 1845; duty 2½ cents per pound."

A bright yellow, moist sugar, having a very good grain for muscovado, and a bright crystalline appearance.

$e = 0.25$; $a = 37°.42$;
$d = 1.0996$; $a'' = -11°.38$;
$t = 71°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 87.85.

131. Received from the custom-house, Boston, marked "Sample of 44 hogsheads of brown sugar, imported into Boston from Mayaguez, in the barque Ed. Kippoch, by Robert Bailey, September 4, 1845; duty 2½ cents per pound."

A light yellow, moist sugar, having a good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 39°.4$;
$d = 1.1055$; $a'' = -12°.3$;
$t = 65°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.71.

132. Received from the custom-house, Boston, marked "Sample of 17 hogsheads of brown sugar, imported from Mayaguez, in the barque Ed. Kippoch, by Robert Bailey, September 4, 1845; duty 2½ cents per pound."

A light yellow, moist sugar, having only a tolerable grain; crystals small.

$e = 0\ 25$; $a = 40°.54$;
$d = 1.1041$; $a'' = -11°.5$;
$t = 65°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.20.

133. Received from the custom-house, Baltimore, marked "Schooner Gallant Mary, Mayaguez, P. R., August 28, 1845, M.; to Kirkland, Chase & Co."

A light yellow, moist sugar, having a rather good grain, and bright crystalline appearance; large lumps of a dark color occurring frequently.

$e = 0.25$; $a = 38°.4$;
$d = 1.1030$; $a'' = -10°.5$;
$t = 65°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 87.55.

134. Received from the custom-house, Baltimore, marked "Schooner Gallant Mary, Mayaguez, P. R., August 28, 1845, 'Joseph;' to Kirkland, Chase & Co."

A light yellow, slightly moist sugar, having a good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 38°.8$;
$d = 1.1064$; $a'' = -11°.3$.
$t = 63°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 89.66.

135. Received from the custom-house, Baltimore, marked "Brig Waterwitch, Mayaguez, *Dukey*, 46 hogsheads, to Kirkland, Chase, & Co.; September 19, 1845."

A light yellow, very moist sugar, having a tolerable grain, and a bright crystalline appearance.

$e = 0.25$; $a = 38°.8$;
$d = 1.1014$; $a'' = -12°$;
$t = 68°.7$ F.; $n = 0.0$.

Per cent. of cane sugar, 91.43.

136. Received from the custom-house, Baltimore, marked "Brig Waterwitch, from Mayaguez, '*Nadal*,' 45 hogsheads, to Kirkland, Chase & Co.; September 19, 1845."

A light yellow, and very moist sugar, having a rather good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 38°.1$;
$d = 1.10275$. $a'' = -11°.1$;
$t = 67°$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.27.

137. Received from the custom-house, Baltimore, marked "Brig Waterwitch, from Mayaguez, *Amistad TD*, 36 hogsheads, to Kirkland, Chase & Co.; September 19, 1845."

A very light yellow, moist sugar, having a rather good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 39°.8$;
$d = 1.1071$; $a'' = -11°.7$;
$t = 51°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.09.

138. Received from the custom-house, Baltimore, marked "Brig Waterwitch, Mayaguez, P. R., V, 9 hhds., to Kirkland, Chase & Co.; September 19, 1845."

A light-colored, moist sugar, having a very good grain, and a bright crystalline appearance.

$e = 0.75$; $a = 40°$;
$d = 1.1067$; $a'' = -12°.4$;
$t = 65°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.73.

139. Received from the custom-house, New York, marked "Imported in brig Port Leon, from Mayaguez, P. R., September 22,

1845, by J. W. Cudbert, 10 hhds. brown sugar, marked RM; duty 2½ cents per pound."

A light yellow, moist sugar, having a tolerable grain, with small hard lumps occurring frequently.

$e = 0.25$; $a = 37°.5$;
$d = 1.1009$; $a'' = -9°.9$;
$t = 65°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 85.

*Muscovado sugar from Guayama, P. R.*

140. Received from the New York custom-house, and marked "Brig Wallace, from Guayama, P. R.; arrived September 3, 1845, marked *Enrequeta, Guayama, AH;* 122 hhds. brown sugar, imported by B. DeForest & Co.; duty 2½ cents per pound."

A deep yellow, moist sugar; grain good, and gritty.

$e = 0.25$; $a = 40°$;
$d = 1.1017$; $a'' = -11°.1$;
$t = 80°$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.64.

141. Received from the New York custom-house, and marked "Imported in brig Ansonia, from Guayama, P. R., September 6, 1845, by Chastelain & Ponvert, 145 hhds. brown sugar; duty 2½ cents per pound."

A dull yellowish-white, moist sugar, of an inferior grain; lumps of pasty sugar occurring in it.

$e = 0.25$; $a = 38°.2$;
$d = 1.1001$; $a'' = -11°$;
$t = 79°$ F., $n = 0.9$.

Per cent. of cane sugar, 88.48.

142. Received from the custom-house, New York, and marked "Brig Wallace, from Guayama, P. R.; arrived September 3, 1845; *SN*, 13 bbls. brown sugar; *H^da Concordia Guayama, P. R.*, 7 hhds. brown sugar, imported by G. Wheelwright; duty 2½ cents per pound."

A deep bright yellow, moist sugar; grain good.

$e = 0.25$; $a = 40°.1$;
$d = 1.1030$; $a'' = -11°.2$;
$t = 82°.5$; $n = 0.9$.

Per cent. of cane sugar, 91.92.

143. Received from the custom-house, New York, and marked "Imported in brig Russia, from Guayama, P. R., August 28, 1845,

by J. B. Lasala & Co., 33 hhds. sugar, marked C; duty 2½ cents per pound."

A deep yellow, moist sugar, of good grain.

$e = 0.25$; $a = 41°\ 1$;
$d = 1.1045$; $a'' = -11°.6$;
$t = 86°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 94.42.

144. Received from the New York custom-house, and marked "Imported in brig Russia, from Guayama, P. R., August 28, 1845, by J. B. Lasala & Co., 32 hhds. brown sugar, marked HRP; duty 2½ cents per pound."

A light yellow moist sugar, having a rather hard grain; crystalline appearance somewhat dull.

$e = 0.25$ $a = 39°.6$;
$d = 1.1005$; $a'' = -11°$;
$t = 83°$ F.; $n = 0.9$.

Per cent. of cane sugar, 90.95.

145. Received from the custom-house, New York, marked, "Imported in brig Russia, from Guayama, P. R., August 28, 1845, by J. B. Lasala & Co., 35 hhds. sugar, marked *Monserrati*. Duty 2½ cents per lb."

A light yellow, moist sugar, having a good grain and a rather bright crystalline appearance.

$e = 0.25$ $a = 39°.6$;
$d = 1.1041$; $a'' - 11°.95$;
$t = 66°.4$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.43.

146. Received from the custom-house, New York, marked "Imported in brig Ansonia, from Guayama, P. R., September 6, 1845, by Benjamin DeForest & Co., 11 hhds. sugar, marked DFXC. Duty 2½ cents per lb."

A dull yellow, very moist sugar, having an inferior grain and a pasty, mealy feeling when rubbed between the fingers; slight and dull crystalline appearance.

$e = 0.25$; $a = 38°.2$;
$d = 1.1035$; $a'' = -12°.7$;
$t = 66°.4$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.52.

147. Received from the New York custom-house, and marked "Brig Wallace, from Guayama, P. R.; arrived September 3, 1845; 14 hhds. brown sugar; imported by Chastelain & Ponvert. Duty 2½ cents per lb."

A deep yellow, moist sugar, having a tolerable grain and crystalline appearance.

$e = 0.25$; $a = 39°.8$;
$d = 1.1016$; $a'' = -10°.9$;
$t = 84°$ F.; $n = 0.9$.

Per cent. of cane sugar, 90.90.

148. Received from the New York custom-house, and marked "Imported in brig Ansonia, from Guayama, P. R., September 6, 1845, by Chastelain & Ponvert, 19 barrels sugar. Duty 2½ cents per lb."

Rather dark yellow and very moist sugar, of an inferior grain; appearance crystalline.

$e = 0.25$; $a = 36°.1$;
$d = 1.095$; $a'' = -12.9$;
$t = 55°.8$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.90.

*Muscovado sugar from Guayanilla.*

149. Received from the New York custom-house, and marked "Imported in brig Betsey and Jane, from Guayanilla, September 10, 1845, by Maitland, Comrie & Co., 22 hhds. brown sugar, marked L. Duty 2½ cents per lb."

$e = 0.25$; $a = 39°.38$;
$d = 1.1023$; $a'' = -12°.4$;
$t = 69°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.12.

150. Received from the custom-house, New York, marked "Imported in brig Betsey and Jane from Guayanilla, September 10, 1845, by Maitland, Comrie & Co., 95 hhds. brown sugar, marked MS. Duty 2½ cents per lb.

A deep yellow, moist sugar, having a good grain and large crystals.

$e = 0.25$; $a = 38°15$;
$d = 1.105$; $a'' = -11°.6$;
$t = 60°$ F.; $n = 0.9$.

Per cent. of cane sugar, 89.17.

151. Received from the custom-house, New York, marked "Imported in brig Betsey and Jane, from Guayanilla, September 10, 1845, by Maitland, Comrie & Co., 47 bbls. brown sugar marked VH. Duty 2½ cents per lb."

A dull yellow, moist sugar, having only a tolerable grain.

$e = 0.25$; $a = 39°.7$;
$d = 1.1025$; $a'' = -12°$;
$t = 69°$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.90.

152. Received from the New York custom-house, and marked "Imported in brig Betsey and Jane, from Guayanilla, September 10, 1845, by Maitland, Comrie &, Co., 17 hhds. brown sugar, marked M. Duty 2½ cents per lb."

A dull yellow and very moist sugar, having a tolerable grain and a crystaline appearance; lumps of a darker color occurring in it.

$e = 0.25$; $a = 38°.5$;
$d = 1.0991$; $a'' = -10°.8$;
$t = 75°.1$; $n = 0.9$.

Per cent. of cane sugar, 88.71.

*Muscovado sugar from Arecibo, P. R.*

153. Received from the custom-house, New York, marked "Arrived August 4, 1845; samples of brown sugar, per brig Margaretta, from Arecibo, P. R. Imported by F. S. Schlesinger."

A light yellow, moist sugar, having a rather good grain and a rather bright crystalline appearance.

$e = 0.25$; $a = 41°.1$;
$d = 1.102$; $a'' = -11°.7$;
$t = 80°$ F; $n = 0.9$.

Per cent. of cane sugar, 94 74.

154. Received from the custom-house, Baltimore, marked "Brig Commerce, Arecibo, HL, 29 hhds., to William Howell & Son, September 13, 1845."

A very light yellow, quite dry sugar, having a bright crystalline appearance and a very good grain.

$e = 0.25$; $a = 40°.1$;
$d = 1.1032$; $a'' = -11°.6$;
$t = 71°$; $n = 0.9$.

Per cent. of cane sugar, 92.69.

155. Received from the custom-house, Baltimore, marked "Brig Commerce, Arecibo, '*Puente Bagasa.*' To Wm. Howell & Son. September 13, 1845."

A light yellow, moist sugar, having a very good grain and a bright crystalline appearance.

$e = 0.25$ $a = 39°.4$;
$d = 1.101$; $a'' = -11°$;
$t = 72°.4$ F.; $n = 0.9$.

Per cent. of cane sugar, 90.49.

156. Received from the custom-house, Baltimore, marked "Brig Commerce, Arecibo, *HABRA*, 11 hhds.; Howell & Son. September 13, 1845."

A light yellow, moist sugar, having a good grain and a bright crystalline appearance.

$e = 0.25$; $a = 38°$;
$d = 1.101$; $a'' = -11°.6$;
$t = 64°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 89.21.

157. Received from the custom-house, Baltimore, marked "Brig Commerce, Arecibo, SB, 9 hhds., to Wm. Howell & Son. September 13, 1845."

A light yellow, moist sugar, having a good grain and bright crystalline appearance.

$e = 0.25$; $a = 37°.5$;
$d = 1.1005$; $a'' = -11°.8$;
$t = 63°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 88.83.

158. Received from the custom-house, Baltimore, marked "Brig Frances Jane, Arecibo, '*Esperanza*,' to Kirkland, Chase & Co. August 18, 1845.

A light yellow, rather dry sugar, having a very good grain and a bright crystalline appearance.

$e = 0.25$; $a = 41°.2$;
$d = 1.1064$; $a'' = -11°.9$;
$t = 68°$ F.; $n = 0.9$.

Per cent. of cane sugar, 94.98.

159. Received from the Baltimore custom-house, and marked "Brig Commerce, from Arecibo, St. Francisco, 30 hhds. Wm. Howell & Son. September 13, 1845."

A very light yellow, moist sugar, having a good grain and a bright crystalline appearance.

$e = 0.25$; $a = 40°.3$;
$d = 1.1022$; $a'' = -11°.5$;
$t = 75°.4$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.96.

160. Received from the custom-house, Baltimore, marked "Brig Commerce, Arecibo, P. R., September 13, 1845, 23 hhds., HC. To Wm. Howell & Son."

A dingy yellow, rather dry sugar, having a good grain and a crystalline appearance.

$e = 0.25$; $a = 38°.7$;
$d = 1.1071$; $a'' = -11°.5$;
$t = 52°.5$ F.; $n = 0.9$.

Per cent of cane sugar, 89.75.

161. Received from the Baltimore custom-house, and marked "Brig Commerce, from Arecibo, P. R.—ASA, 4 hhds. To William Howell & Son. September 13, 1845."

A light yellow, and quite dry sugar, having a good grain, and a rather bright crystalline appearance; lumps of a harder grain occurring frequently.

$e = 0.25$; $a = 39°.5$;
$d = 1.1007$; $a'' = -11°.1$;
$t = 76°$ F.; $n = 0.9$.

Per cent. of cane sugar, 90.85.

162. Received from the custom-house, Baltimore, marked "Brig Commerce, Arecibo, P. R. '*Monte Grande*,' 17 hhds. Wm. Howell & Son. September 13, 1845."

A yellow, moist sugar, having a rather good grain and a crystalline appearance.

$e = 0.25$; $a = 38°$;
$d = 1.0997$; $a'' = -10°.9$;
$t = 80°$ F.; $n = 0.9$.

Per cent. of cane sugar, 87.94.

163. Sugar from Cienfuegos.—Received from the custom-house, Boston, marked "Sample of 100 hhds. Muscovado sugar, imported into Boston, from Cienfuegos, in the brig Eliza Burgess, by Benjamin Burgess & Sons. August 25, 1845. Duty 2½ cents per pound."

A light yellow, very moist sugar, having a tolerable grain and a bright crystalline appearance.

$e = 0.25$; $a = 38°.72$;
$d = 1.1057$; $a'' = -12°.1$;
$t = 67°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.

164. Sugar from Laguayra.—Received from the Philadelphia custom-house. A dark brown, moist sugar, having a good grain; gritty between the fingers; large lumps, with veins of a darker color occurring in it.

$e = 0.25$; $a = 40°.2$;
$d = 1.0975$; $a'' = -11°.6$;
$t = 17°.5$ C.; $n = 0.9$.

Per cent. of cane sugar, 93.44.

165. Sugar from Para.—Received from the New York custom-house, and marked "Brig Lowell, from Para, 235 bbls. brown sugar; arrived September 19, 1845. Imported by Allen & Paxon. Duty 2½ cents per pound."

A deep brown, moist sugar, having an ordinary grain; very slightly gritty between the fingers; large dark lumps occurring in it.

$e = 0.25$; $a = 36°.75$;
$d = 1.1002$; $a'' = -10°.3$;
$t = 81°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 84.55.

166. Sugar from Naguabo.—Received from the New York custom-house, and marked "Imported in brig Sabine, from Naguabo, P. R., September 24, 1845, by J. B. Lasala & Co., 236 hhds., marked J. S. Duty 2½ cents per pound."

A yellowish white, moist sugar, having a tolerably good grain.

$e = 0.25$; $a = 41°$;
$d = 1.1038$; $a'' = -11°.3$;
$t = 77°.5$; $n = 0.9$.

Per cent. of cane sugar, 93.61.

*Muscovado sugar from Halifax.*

167. Received from the custom house, Boston, marked "Sample of 20 hhds. brown sugar, imported into Boston, from Halifax, in the brig Acadian, by Thomas Tremlett, September 27, 1845. Duty 2½ cents per pound."

A bright yellow, moist sugar, having a rather good grain, and a crystalline appearance.

$e = 0.25$; $a = 39°.6$;
$d = 1.1054$; $a'' = -11°.6$;
$t = 56°.8$; $n = 0.9$.

Per cent. of cane sugar, 91.18.

168. Received from the custom-house, Boston, marked "Sample of 14 bbls. brown sugar, imported into Boston, from Halifax, in the brig Acadian, by Thomas Tremlett, September 27, 1845. Duty 2½ cents per pound."

A light-grayish yellow, moist sugar, having a good grain, and a bright crystaline appearance.

$e = 0.25$; $a = 40°$;
$d = 1.1012$; $a'' = 10°.9$;
$t = 81°$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.38.

169. Received from the Boston custom-house, and marked "Sample of 5 hhds. brown sugar, imported into Boston, from Halifax, in the brig Acadian, by Thomas Tremlett, September 27, 1845. Duty 2½ cents per pound.

A light yellow, moist sugar, having a rather inferior grain; appearance bright and crystalline.

$e = 0.25$; $a = 39°$;
$d = 1.1002$; $a'' = -11°.9$;
$t = 75°.5$ F; $n = 0.9$.

Per cent. of cane sugar, 91.63.

170. Received from the custom-house, Boston, marked "Sample of 20 hhds. brown sugar, imported into Boston, from Halifax, in the brig Acadian, by Thomas Tremlett, September 5, 1845. Duty 2½ cents per pound."

A light yellow, moist sugar, having a rather good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 40°$;
$d = 1.1025$; $a'' = 11°$;
$t = 83°$ F.; $n = 0.9$.

Per cent. of cane sugar, 91.52.

171. Received from the custom-house, Boston, marked "Sample of 55 hhds. brown sugar, imported into Boston, from Halifax, in the brig Acadian, by Thomas Tremlett, September 5, 1845. Duty 2½ cents per pound."

A yellow, very moist sugar, having a tolerable grain.

$e = 0.25$; $a = 39°.3$;
$d = 1.1022$; $a'' = -10°.64$;
$t = 59°.6$ F.; $n = 0.9$.

Per cent. of cane sugar, 89.56.

172. Received from the custom-house, Boston, marked "Sample of 37 hhds. brown sugar, imported into Boston, from Halifax, in the brig Acadian, by Thomas Tremlett, September 27, 1845. Duty 2½ cents per pound."

A light yellow, moist sugar, having a good grain, and bright crystalline appearance.

$e = 0.25$; $a = 38°.76$;
$d = 1.1032$; $a'' = -11°.86$;
$t = 64°.3$ F.; $n = 0.9$.

Per cent. of cane sugar, 90.87.

173. Received from the custom-house, Boston, marked "Sample of 16 hhds. brown sugar, imported into Boston, from Halifax, in the brig Acadian, by Thomas Tremlett, September 27, 1845. Duty 2½ cents per pound."

A rather dark yellow, moist sugar, having a rather good grain, and crystalline appearance.

$e = 0.25$; $a = 38°.33$;
$d = 1.1015$; $a'' = -11°.76$;
$t = 72°$ F.; $n = 0.9$.

Per cent. of cane sugar, 90.13.

174. Received from the custom-house, Boston, marked "Sample of 80 hhds. brown sugar, imported into Boston, from Halifax, in schooner Rainbow, by Chas. S. Brown & Co., September 22, 1845. Duty 2½ cents per pound."

A light yellow, moist sugar, having a good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 40°.06$;
$d = 1.107$; $a'' = -12°.84$;
$t = 65°.1$ F.; $n = 0.9$.

Per cent. of cane sugar, 94.72.

175. Received from the custom-house, Boston, marked "Sample of 75 hhds. brown sugar, imported into Boston, from Halifax, in the schooner Boston, by Thomas Tremlett, October 8, 1845. Duty 2½ cents per pound."

A very moist, yellow sugar, having a tolerable grain, and a bright crystalline appearance.

$e = 0.25$; $a = 39°.68$;
$d = 1.1059$ $a'' = -12°$;
$t = 64°.2$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.52.

176. Received from the custom-house, Boston, marked "Sample of 23 hhds. brown sugar, imported into Boston, from Halifax, in the brig Acadian, by Thomas Tremlett, September 17, 1847. Duty 2½ cents per pound."

A light yellow, moist sugar, having a good grain and a bright crystalline appearance.

$e = 0.25$; $a = 39°.94$;
$d = 1.1025$; $a'' = -11°.44$;
$t = 70°.5$ F.; $n = 0.9$.

Per cent. of cane sugar, 92.21.

177. Received from the custom-house, Baltimore, marked "Schooner Comet, from St. Thomas, August 23, 1845, A C H, 24 hhds., to Johnson & Trovers."

A very light-colored, moist sugar, having a rather good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 38°.5$;
$d = 1.1024$; $a'' = -12°.8$;
$t = 64°.9$. $n = 0.9$.

Per cent. of cane sugar, 92.10.

178. Lovering's "*crushed sugar*"—from a grocer.

A very white, brilliant, crystalline sugar; grain hard and firm.

$e = 0.25$; $a$ 42°.5;
$d = 1.1055$; $a''$ — 13°;
$t = 74°$ F.; $n$ 0.9.

Per cent. of cane sugar, 99.39.

Woolsey's *double-refined loaf sugar*—from a grocer.

A white, brilliant sugar, of a fine crystalline structure; grain hard.

By the copper test of Trommer, it gives a very slight red precipitate.

$e = 0.25$; $a = 42°.2$;
$d = 1.1054$; $a'' = -12°.7$;
$t = 74°$ F.; $n = 0.9$.

Per cent. of cane sugar, 98.34.

180. Brown sugar of Cuba; *Quebrado florete.* U. S. standard; from New Orleans custom-house.

A light whitish yellow, dry sugar, having a good, fine grain, with a crystalline appearance.

$e = 0.25$; $a = 42°$;
$d = 1.10567$; $a'' = -12°.9$;
$t = 75°$ F.; $n = 0.9$.

Per cent. of cane sugar, 98.30.

181. Inferior white, from Cuba; (*Blanco segunda.*) United States standard; from New Orleans custom-house.

A dull white, dry, fine-grained, and gritty sugar; grain hard; appearance crystalline.

$e = 0.25$; $a = 42°$;
$d = 1.10563$; $a'' = 12°.85$;
$t = 74°$ F.; $n = 0.9$.

Per cent. of cane sugar, 98.32.

182. "New Orleans prime sugar." Muscovado sugar.

A light yellow, moist sugar, having a good grain, and a bright crystalline appearance.

$e = 0.25$; $a = 40°.5$;
$d = 1.1035$; $a'' = -11°.75$;
$t = 87°$ F.; $n = 0.9$.

Per cent. of cane sugar, 93.69.

183. "New Orleans prime white ('*clarified*') sugar."

A white, fine, and good grained sugar.

$e = 0.25$; $a = 42$;
$d = 1.1049$; $a'' = -12°.6$;
$t = 85°$ F.; $n = 0.9$.

Per cent. of cane sugar, 97.79.

184. New Orleans raw sugar, from Messrs. Rutter, Patterson, and Newhall.

A moist, yellow sugar, of a good grain and fresh odor.

$e = 0.25$; $= a\ 39°.7$;
$d = 1.0978$; $= -a''\ 11°$;
$t = 27°.5$ C.; $= n\ 0.9$.

Per cent. of cane sugar, 92.74.

185. New Orleans sugar.

A light-colored, moist sugar, of a good grain, and bright crystalline appearance.

$e = 0.25$; $a = 37°.9$;
$d = 1.100$; $a'' = -11°$;
$t = 86°$ F.; $n = 0.9$.

Per cent. of cane sugar, 87.91.

186. Maple sugar.

The sample analyzed was manufactured and sold in cakes of a dark color, having a peculiar odor; grain not good.

$e = 0.25$; $a = 33°.7$;
$d = 1.0943$; $a'' = -9°.9$;
$t = 32°$ C.; $n = 0.9$.

Per cent. of cane sugar, 78.83.

187. "*Clarified sugar*," manufactured by Mr. Broome, of Philadelphia, from molasses, by evaporation in a vacuum pan.

A yellow and rather dry sugar, of inferior grain.

$e = 0.25$; $a = 37^{\circ}.2$;
$d = 1.0961$; $a'' = -10^{\circ}.5$;
$t = 24^{\circ}.7$ C.; $n = 0.9$.

Per cent. of cane sugar, 86.

188. *Bastard sugar*, from Messrs. J. S. Lovering & Co.

A dark yellow, and very moist sugar, having large crystals, and gritty; burnt smell.

$e = 0.25$; $a = 35^{\circ}$;
$d = 1.0978$; $a'' = -9^{\circ}.3$;
$t =$ $n = 0.9$.

Per cent. of cane sugar, 78.28.

## EXPLANATION OF THE PLATES.

### Plate I.

*Taylor's filter.*—Fig. 1—Vertical section. Fig. 2—Plan. Fig. 3—Enlarged view of one of the bags. Fig. 4—Conical tube for attachment of bags enlarged.

*aa*, the filtering bags.

*b*, cock for drawing off filtered sirup.

*cc*, tubes of attachment of the bags.

*d*, door for putting in and removing bags.

*Action of the filter.*—The sirup is placed in the space *A*, and passes through the tubes *cc*, which communicate with the bags through which the sirup filters. The conical tubes *c* are surrounded by the openings of the bags, and clasped by a sliding ring, which binds them fast. The filtered sirup is drawn off by the cock *b*.

*Dumont's filter.*—Fig. 5.

*aa*, a double bottom of sheet copper pierced with holes, on which a wet cloth is laid.

*b*, cock for removing the filtered sirup.

*cc*, upper partition of metal pierced with holes, furnished with a handle.

*e*, a hollow metal ball attached to the cock of the supply-pipe.

This apparatus is filled with coarse-grained boneblack in the space *A*, between the pierced partitions *aa* and *cc*. The space *B* is designed to receive the sirup through the feeding-pipe, the supply of which is adjusted to a constant level by a self-regulating cock. The filtered sirup is received in *C*, and flows off by the cock *b*.

Fig. 6.—Perspective view of a simple *lever-press* employed in France for extracting sirup from the scum separated in defecation, and which acts constantly.

Fig. 7.—Vertical section of a *defecator*, as improved by M. Hallette, with an external bottom of cast iron.

*aa*, internal copper bottom.

*bb*, cast-iron bottom.

*c*, cock with three openings, for withdrawing the liquor at different levels.

*Bascule pan.*—Fig. 8—Vertical section. Fig. 9—Horizontal section.

*a*, a shallow pan, which turns upon an axis; may be tilted by means of a pulley, and emptied by a spout. The dotted outlines in Fig. 8, represent the position of pouring.

### Plate II.

*Taylor's evaporating pan.*—Fig. 1—Elevation. Fig. 2—Horizontal section of the tubes. Fig. 3—Plan.

*A*, the pan itself, supported by four columns.

*B*, copper steam-pipes, arranged so as to form a horizontal grate.

*C*, main steam-pipe and axis divided longitudinally by the diaphragm *a*; one end of which is conical, and pierced laterally for the escape-pipe *F*. Upon this axis the grate turns so as to permit the pan to be easily cleaned.

*D*, internal tubes enveloped by the pipes *B*.

*E*, a double cock, opened or shut at pleasure by the handle *V*.

*F*, the curved escape-pipe, which connects with

*G*, the tube which conducts the condensed steam back to the boiler.

*H*, cock to empty the pan when the sirup is concentrated.

The steam follows the course indicated by the arrows in Fig. 2, entering C on one side of the diaphragm, passing through the pipes *D* and *B*, and returning by *F* and *G* to the boiler.

*Dubrunfaut's pan.*—Fig. 4—Elevation. Fig. 5—Plan.

*A*, the evaporating pan.

*B*, the bent steam-pipe.

*a*, cock for admitting steam.

*b*, cock for escape of steam and water of condensation.

*c*, handle for opening and shutting the discharge valve, *e*.

*d*, pipe for filling the pan with sirup.

*f*, a wooden cover, preventing the escape of vapor into the room, and causing it to pass off by

*g*, the wooden chimney.

*Hallette's serpentine steam-pan.*—Fig. 6—Plan. Fig, 7—Front elevation of the pan.

*a*, the steam-pipe.

*bb*, escape-pipes for the steam which circulates in the serpentine.

*c*, the discharge pipe for the concentrated sirup.

Fig. 8—A *copper basin*, used for filling moulds.

## Plate III.

*Roth's system.*—Fig. 1—The condenser. Fig. 2—Vertical section of the vacuum pan. Fig. 3—Section in the line *xx*.

*A*, the steam-pipe.

*B*, large iron vessel for condensing.

*C*, copper vacuum pan, with a double bottom.

*b*, lateral pipe conveying steam into the space *yy*.

*d*, tube for conveying steam into the space *C*, and forming a vacuum.

*e*, serpentine tube, heated by steam.

*f*, tube for drawing sirup from the reservoir *r*, into the vacuum pan.

*g*, cock for discharging the concentrated sirup.

*h*, escape pipe for removing condensed steam from *yy*.

$h^1$, pipe for removing condensed steam from the serpentine.

*ii*, tube of communication between *c*, the vacuum pan, and *B*, the condenser.

*jj*, tube for admitting cold water from the reservoir *l*, into the condenser *B*.

*l*, cold water reservoir.

*mm*, diaphragms to extend the surface in contact between the steam and the water.

*n*, cock for the escape of the air when the vacuum is to be formed, and for its admission when the contents of the pan are to be removed.

*o*, gauge indicating the pressure in the condenser.

*p*, tube showing the level of the water in the condenser.

*q*, cock for removing water from the condenser.

*r*, reservoir for sirup.

PLATE IV

*System of M. Degrand,* (as constructed by MM. Derosne and Cail.) Fig. 1—Plan of the condenser. Fig. 2—Elevation of the apparatus.

A, A, an oscillating steam engine, working an air-pump, *e*, *e*, to form a vacuum in B.

B, a vacuum pan, heated by a serpentine *a*, *a*.

C, a reservoir, to hold any syrup which may accidently pass through the pipe, *c*.

D, a bent tube, intended to aid in forming the vacuum in B, by condensation.

G, reservoir or cistern for dilute juice.

*a*, *a*, serpentine tube, for heating B.

*b*, the cock for discharging concentrated syrup from B.

*c*, pipe between the pan B, and reservoir C.

*d*, *d*, pipe betweeen the condenser D, and the air-pump *e*, *e*.

*e*, *e*, air-pump worked by the engine A, A.

*g*, *g*, copper reservoir for the juice which has flowed over the surface of the bent tube D.

*i*, *i*, pipe conveying the juice from *g*, *g*, into a cistern.

*n*, *n*, troughs for distributing the juice in fine streams over the bent tube D.

*o*, supply pipe of the troughs, *n*, *n*.

*s*, supply pipe of the steam engine, A.

*Dutrone's crystallizing box.*—Fig. 3—Transverse section.

*A*, the box itself.

*b*, *b*, the upright supports.

*c*, *c*, sections of strips of wood upon which the box rests.

*d*, *d*, the inclined bottom, perforated by numerous holes in the middle line of junction for the escape of the molasses.

*e*, *e*, troughs or channel for conveying the molasses to the cistern, covered with cement.

*Payen's decolorimeter.*—Fig. 4—Side and front elevation.

*CD*, tube for holding the sirup.

*B*, sliding tube, with a graduated scale.

*P*, closed space between two glass disks filled with standard colored liquor.

PLATES V, VI, AND VII.

*System of Rillieux.*—Plate V—Front elevation. Plate VI, fig. 1—Plan of one of the evaporating pans; Fig. 2—Plan of frame-work and pipes. Plate VII, fig. 1—Transverse section; Fig. 2—Side elevation, half in section.

*A*, the evaporating pan.

*aa*, the main steam-pipe.

*bb*, the pipe conveying the vapor from the first pan to the chamber *k*.

*cc*, pipe conducting it into the second pan.

*dd*, pipe for the escape of vapor from the second pan into a box *k*, communicating with the air-pump *y*, by means of the pipes *i* and *h*.

*ee*, the steam-pipe of the last evaporating pan.

*ff*, pipe for escape of vapor from the last pan.

*g*, pipe conveying the vapor from the first pan to the last, and connecting with *e*.

*hh*, pipe connecting the second and third pans with the air-pump *y*.

*i*, pipe connecting *h* with *k* and *d*.

*k*, *k*, steam-chambers or boxes.

*l*, *l*, dome or cupola from which the vapor is taken by the pipe *s*.

*m*, *m*, handles for opening the conical valves *o*.

*n*, *n*, pipes for supplying high steam to different parts of the apparatus.

*o*, *o*, conical valves.

*p*, *p*, handles of the discharge valves.

*q*, discharge valve of the last pan.

*r*, *r*, internal flues or tubes.

*s*, pipe supplying high steam to the vacuum pipes to drive out the air.

*t*, valve for the pipe *s*.

*u*, glass disk for observing the interior of the pan.

*v*, diaphragm or bridge separating the high steam chamber from that of the vapor

*ww*, double case.

*xx*, escape-pipe conducting the vapor from the dome *l*.

*y*, the air-pump.

*zz*, the supporting frame-work of wood.

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30th Congress, 1st Session. [SENATE.] Executive, No. 50.

# LETTER

FROM

# THE SECRETARY OF THE TREASURY,

COMMUNICATING

*A report of researches on hydrometers and spirituous liquors, made under the superintendence of Professor A. D. Bache, by Professor R. S. McCulloh.*

---

JUNE 2, 1848.

Read, and ordered that 10,000 copies be printed for the use of the Senate, together with the former reports relating to the same series of scientific researches, under the revision of Professor McCulloh.

---

TREASURY DEPARTMENT,
*June* 1, 1848.

SIR: Herewith, I have the honor to transmit to the Senate a letter from Professor A. D. Bache, superintendent of weights, measures, balances, &c., communicating a report of scientific researches on hydrometers, spirituous liquors, &c., made, under his superintendence, by Professor R. S. McCulloh, melter and refiner of the mint of the United States, in compliance with a request of this department, and for the purpose of enabling the Secretary of the Treasury, in the exercise of authority conferred upon him by an act of Congress, approved January 12, 1825, to adopt and institute a more accurate hydrometer, in lieu of that now used for for ascertaining the strength of spirituous liquors.

Very respectfully, your obedient servant,

R. J. WALKER,
*Secretary of the Treasury.*

To the Hon. GEORGE M. DALLAS,
*Vice President of the United States,*
*and President of the Senate.*

*Letter of Professor A. D. Bache, superintendent of weights, measures, and balances, transmitting a second report on inquiries and researches relating to hydrometers, &c., made under his superintendence by Professor R. S. McCulloh.*

OFFICE OF WEIGHTS AND MEASURES,
*May* 29, 1848.

SIR: I have the honor to submit, herewith, a second report on hydrometers, by Professor R. S. McCulloh, containing the results of inquiries and researches made under my superintendence, and proposing to the department a course of action, in which I fully concur. Of this report I propose to make a brief analysis, as leading to the conclusions upon which action by the department is recommended.

In a former report, made in 1845, to one of your predecessors, the circumstances under which these researches were undertaken (by request of the Hon. John C. Spencer) are stated, and they are briefly recapitulated by Professor McCulloh, in the first chapter of the present report. It is due to Professor McCulloh to add, that since the period of his employment in the United States mint, these researches have been continued, and those on sugar have been completed, in the midst of engrossing and arduous duties, without compensation. The superintendence was undertaken by me originally, and has been executed also without compensation.

In the report of 1845, just referred to, a complete theory of the hydrometer was given, the different scales in use described; the advantages of the centesimal scale hydrometer insisted on, and the manner of graduating and using it explained. The mode of making and graduating hydrometers was given. The principal hydrometers of different countries were described, and their theory established. The results of different experiments on the expansion of water were discussed, and those of liquids composed of mixtures of alcohol and water were collected and represented graphically. The subject of the *proofs* of liquors was discussed, and the investigations of different hydrometers in use were compared.

The present report consists of four chapters. In the first is contained a brief notice, or account, of the authority and circumstances under which the work has been performed, of the manner of its execution, and of the resulting measures proposed to the action of the department.

The second contains an elaborate account of researches in relation to the specific gravities of alcoholic liquids, made by authority of European governments, or by private individuals, for scientific purposes.

The third contains new researches on the specific gravities of alcoholic liquids, intended to verify, generally, those of previous experimenters.

The fourth chapter gives the correspondence between the degrees of Dycas's hydrometer, and the per centage by bulk, or weight, of alcohol in various mixtures.

The report closes with an account of the examination of different hydrometers actually used at some of the custom-houses of the United States.

As the results obtained by Gilpin and Blagden, under the direction of the Royal Society of London, and for the British government, have stood the test of repeated re-examination, Professor McCulloh assumes them as standard, and gives a minute account of their methods of experimenting, with all the precautions taken, their results, the criticisms made upon them, the repetition of portions of the experimental work by the authors themselves, their comparative trials of other suggested methods of working, and their recommendations in regard to the manner of collecting revenue on alcoholic liquids, and to the instrument to be used. These researches are contained in three memoirs, occupying some two hundred pages of the transactions of the Royal Society, and extending over a period of six years.

Instead of adopting the very satisfactory method proposed by Gilpin and Blagden, a complex and unscientific system was introduced, the defects of which produced a necessity for a second appeal by the British government to the Royal Society, resulting in a report, which is analyzed, and the recommendations and tables contained in which are given by Professor McCulloh.

The inquiries of Professor Tralles for the Prussian government are next analyzed in detail. They led to the introduction of a centesimal hydrometer, adapted to determining per cents. of alcohol contained in a given liquid; the tables being based upon the experimental results of Gilpin and Blagden. The material proposed was glass. This system has not only stood the test of use in Prussia, but has been adopted (with or without modification) in France, Austria, Sweden, and Belgium. An account of other researches in Germany and in Russia is given.

The inquiries which led to the system and instrument, (the centesimal alcoholometer of Gay Lussac,) used in France, are discussed at length. The adoption of a similar system in Sweden is noticed. Recent experiments made in England are analyzed, and their results given.

The labor of comparing these various results, referring to different units of specific gravity of water and of alcohol, and to different temperatures of these two liquids, is very great, and has been most thoroughly performed by Professor McCulloh and his assistants. Comparative tables are given, in which the numbers obtained, directly from experiment or by interpolation, are referred to the same scale. There is thus presented, at one view, a comparison of the best experiments hitherto made on the subject. The method of tracing curves to represent the experimental results is also resorted to for comparison and for verification, by the regularity of the curves. The result of this detailed comparison is, to confirm as accurate the minute experiments of Gilpin and Blagden, before referred to.

The new experiments by Professor McCulloh were not undertaken with a view to go over the ground previously occupied by

others, step by step, but, merely to explore certain points, and to infer from the examination thus made, general agreement or discordance. The precautions to insure accuracy in the experiments are given in detail, the sources and examination of the weights, balances, hydrometers, and thermometers, and of the liquids used, the manipulations employed, the corrections and the final results are given, and compared with one of the best series of experiments discussed in the previous part of the report. The confirmatory character of these results warrants the recommendation of the system based upon them.

In advising the abandonment of the present arbitrary method of "*proofs*," in testing and describing the value of alcoholic liquids, it is necessary to show the connexion between the new system recommended and the old one. A comparison is therefore made, in the first chapter, between Dycas's hydrometer and the centesimal hydrometer, and between the indication of the former, and the per cent. by bulk and weight of alcohol contained in any given liquid, at an ascertained temperature.

The result of the examination, with which the report closes, of different instruments actually in use in the custom-houses of Baltimore, Philadelphia, New York, Boston, Portland, Newburyport, Salem, Bristol, Providence, Newport, and New Haven, in the year 1845, establishes their general inaccuracy and consequent want of uniformity in the collection of the revenue at the different ports.

The recommendations which grow naturally and necessarily out of the inquiries heretofore submitted, the reasons for which are explicitly stated in the introduction to the present report, or in connexion with the different researches, are the following:

1st. That the strength of liquors should not be referred to the arbitrary degrees of an artificial system, as those of Dycas's hydrometer, but be expressed in per cent. of alcohol contained, by volume, or by weight.

2d. That no reference be made to terms of "*proof*," as "*first proof*," "*second proof*," &c., which are from legal enactment, and not commercial use, in ascertaining or describing the strengths of alcoholic liquors; but, that such description be made in per cent., by weight or bulk of contained alcohol.

3d. That all gaugings or measurements of alcoholic liquids be referred to the standard temperature of 60° of Fahrenheit's thermometer.

4th. That, in stating the per cent. by volume of pure alcohol contained in a liquid, it be reduced to its equivalent at the same standard temperature of 60° Fahrenheit.

5th. That the centesimal hydrometer be adopted in detesmining the strength of liquids; and provisionally, until a better instrument is furnished, the centesimal alcoholometer of Professor Tralles be used, with a suitable manual and tables, to accompany the instrument.

Respectfully submitted, by

A. D. BACHE,

*Superintendent of weights, measures, and balances.*

To the Hon. ROBERT J. WALKER,

*Secretary of the Treasury.*

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# REPORT

*To Professor A. D. Bache, of the researches on hydrometers and spirituous liquors, made under his superintendence, by Professor R. S. McCulloh.*

MELTER AND REFINER'S OFFICE,
*United States Mint, Philadelphia, May 26, 1848.*

SIR: I have the honor to submit to you the following report on hydrometers, &c., showing the progress made in the work confided to me, and furnishing all the information which would be needed, if the Secretary of the Treasury should see fit to substitute for the hydrometer now in use another which would be more accurate and entitled to public confidence, in the exercise of the authority conferred upon him by act of Congress approved 12th January, 1825.

1. On the 14th of June, 1844, I was appointed by the Treasury Department your assistant, to make, under your direction, such investigations and experimental researches as might be found necessary to furnish the information in relation to saccharine substances and the manufacture of sugar, called for by act of Congress approved March 3, 1843; and to perform the labor which might be requisite to enable you to comply readily with a request of the Treasury Department, that you would institute suitable experiments on hydrometers, and furnish the results to that department, made by the Hon. John C. Spencer, in a letter of March 13, 1844, (which has been published in Senate Doc. No. 165, 28th Congress, 2d session, p. 4,) in consequence of complaints that the hydrometer used by the officers of the customs, in obedience to act of Congress approved 10th of August, 1790, is inaccurate, and may, therefore, lead to injustice in the collection of the revenue.

2. On the 18th of February, 1845, I submitted to you a report of the progress made in the inquiries, both in relation to sugars and hydrometers, which report has also been published in Senate Doc. No. 165, 28th Congress, 2d session. To it, therefore, I beg leave to refer for much of the information to which these investigations have led—the present report being supplementary to the second section of that just mentioned.

3. When I undertook the task allotted to me, it was understood that the experiments and inquiries in relation to sugar should be considered as entitled to precedence, my employment being in fact dependent solely upon them, and that the researches on hydrometers should therefore receive only so much of my time and attention as could be devoted to them without neglect of the other work—the former being made by order of Congress, the latter only with their sanction, and in compliance with a request of the Secretary of the Treasury.

4. That these secondary investigations should, therefore, have been deferred until those of primary character were completed, except during the short interval in the summer of 1845, when I was waiting for the specimens of sugar, &c., which the officers of the customs were directed to furnish me, was only in fulfilment of the above mentioned conventional understanding.

During that interval I occupied myself with an examination of the condition of the hydrometers used by the inspectors at several of the northern ports, and in seeking information in relation to the art of refining sugar; for which purposes I visited those places, and the principal sugar refineries in them, in obedience to your orders. The results of the examination of the hydrometers, are given in detail in chapter IV. of this report.

5. After my return to Philadelphia, in 1845, my time was chiefly occupied with chemical analyses of the saccharine substances sent to me from the custom-houses, and in making preparations for my contemplated journey to, and work in, Louisiana and Cuba.

During my absence in Cuba it pleased the President, with the consent of the Senate, to confer upon me the appointment which I now hold in the mint of the United States. The performance of the highly responsible duties of my office, after my return in the spring of 1846, and, at the same time, the completion of the analyses and other work required by the researches on sugar, absorbed my attention, and left me little time for hydrometers, &c., until the end of February, 1847, when I had the honor to make to you my final report on sugar, since published in Senate Doc. No. 209, 29th Congress, 2d session.

The year 1847 was one of constant and unusually heavy work in the mint, devolving upon me more than ordinary labor and responsibility; also, some improvements had to be introduced in the melting department. I could not, therefore, prosecute the inquiries and experimental researches on hydrometers energetically, or give them more than a small portion of my time, during that period or until very recently.

6. I have given this extended account of my proceedings, that it may appear, both to yourself and others, to be due to no neglect that the investigations in relation to hydrometers have not long since been completed and fully reported; and certainly I should have much preferred to have brought them to an early termination, if it could have been done without slighting them.

7. In making the numerical calculations required for this report, I was assisted by my friend and former pupil, Woods Baker, esq., who volunteered his services, and labored without pecuniary compensation most indefatigably and efficiently. He generally repeated and verified both my own computations and those of the other assistants; and his mathematical ability and general scientific attainments render his work fully entitled to confidence. I was aided in a similar manner by my former assistant, J. B. Reynolds,

esq., now lecturer on natural philosophy in the Franklin Institute. Mr. Charles Hartshorne and Mr. Alfred Cummings, assistants, also labored industriously and with ability in computing numerical results. Lastly, in my experiments and chemical manipulations, I was assisted by John Monell, esq., employed as foreman in the refining operations of the mint, who aided me in numerous ways, and relieved me of the arduous task of watching and conducting the repeated distillations of alcohol and water, required to obtain the former pure, and keep the latter free from absorbed air.

8. With reference to the numerical calculations, the results of which are given in this report, I wish it to be understood that they were, with few and unimportant exceptions, made by two different persons, independently of each other—one assistant checking the work of another, and my own computations being similarly verified by some one of them. This plan was followed, because I have little faith in the truth of long and laborious numerical computations, unless confirmed by some good method of verification. It is too easy to commit errors in the simplest additions, subtractions, &c.; and few fail to make them often.

9. The formulas, and adopted coefficients of reduction, which were used in the calculations, are given in an appendix to this report; which contains the mathematical theory, not only of this particular work, but also of the determination of the exact weights and specific gravities of bodies generally; and is herewith submitted for your information with reference to the methods I have followed. Whether or not that appendix should be communicated with this report to the Treasury Department, I, however, submit as a question for your judgment and decision. It is a paper purely scientific, and may be too abstract for publication as part of a practical investigation. Probably it would find a more appropriate place in some scientific journal, of convenient reference.

10. The experimental work cannot, in my opinion, yet be considered complete, although it is sufficiently so to justify the Secretary of the Treasury in at once adopting and giving orders for the use of a new and more accurate hydrometer.

Any instrument which would determine specific gravities readily and accurately, so that the corresponding strengths may become known, would answer; and it is, perhaps, best that no legislative action should take place, which would fix upon the country, as heretofore, a very imperfect and faulty system; but that, on the contrary, the authority now given to the Secretary of the Treasury to substitute one hydrometer for another, should continue to be vested in him, in order that, if improvements be invented, they may be introduced without difficulty.

This is the more desirable, because it is very likely that the apparatus you have proposed, of a hollow metallic ball suspended from a spring balance, may be brought to perfection, and would be greatly superior to any hydrometer of the ordinary kind. Those of

metal must be made so thin that the least blow indents them deeply, and destroys them. Besides, they are of difficult construction, and very costly; and glass hydrometers are fragile, though cheap. Your suggested ball and spring balance may have any required degree of strength; but whether the sensibility can be rendered sufficient, and the spring free from derangement, has not yet been satisfactorily tested; and until this is done, the question should remain undecided.

11. Temporarily, and until some more perfect instrument is invented, I recommend the adoption of the centesimal alcoholometer, either of Tralles or Gay Lussac.

That of Tralles is preferable, because the volumes are measured at 60° Fahrenheit, instead of 15° centigrade, equivalent to 59° Fahrenheit, adopted by Gay Lussac; and because it is referred to the density of water at its maximum degree of condensation, instead of 15° cent., and therefore corresponds to the system of weights and measures of the late Mr. Hassler.

12. For either of these instruments, it would be necessary to print a small manual of instructions and tables. This for that of Gay Lussac has already been done in French; a translation could be made of it in a very few days, and with trifling labor. For the instrument of Tralles, it would be necessary to interpolate his tables, given in the succeeding chapter of this report, for every single per cent. The requisite work demanded for this purpose I am willing to perform, with suitable assistance, if it be desired.

13. Whatever doubts may exist as to the propriety of fixing any particular instrument permanently upon the country, I think that none can be for a moment entertained with reference to the basis of all future action on the part of the government in relation to the determination of the strengths of liquors; and I would here respectfully suggest that in all instances the following propositions be adopted, and adhered to:

1st. The strength of a liquor should never be referred to the arbitrary degrees of an artificial system, as those of Dycas's hydrometer, but be expressed in per cent. of alcohol contained by volume or by weight, as is done for mixtures of other substances.

2d. All reference to the terms *first proof*, *second proof*, &c., should hereafter be dropped; those terms being legislative and not commercial, originally created by act of Congress, and having no longer any use, except to invite attempts at fraud.

3d. Spirituous liquor should pay duty proportionally to their strengths, or per cent. of contained alcohol; the rest being water, and valueless: provided, however, that the value does not depend on some peculiar and esteemed flavor, or other quality.

4th. As the volume of any liquid varies with its temperature, so that the same quantity of spirit does not measure the same number

of gallons if gauged at different temperatures, all measurements should be referred to the mean temperature of 60° Fahrenheit.

5th. A cask of liquor would then pay duty on the per cent. by volume of pure alcohol which it contains at 60° Fahrenheit only; this will be determined by multiplying the gauged contents found at any other temperature by such factor or multiplier as will reduce both the indicated strength and measured volume to that temperature. Tables XIII. and XIV., of Tralles, of the succeeding chapter, and the table of *richness* of Gay Lussac—see section 92, below, are tables of such factors.

14. If these few fundamental propositions should be observed in future legislation and administrative regulations, commercial strengths, or *proofs*, may be infinitely varied with the capricious tastes and wishes of the dealers and consumers, without rendering it necessary to modify existing laws; nor will the laws interfere with commercial interests or convenience. The system adopted by the government will be perfectly simple, intelligible, and just; and its simplicity will render frauds of much more difficult achievement.

Fortunately, also, at the present time the tariff levies duties proportional to the values of spirituous liquors, and is therefore exactly adapted to the introduction of a new mode of expressing their strengths by per cent. of the article contained which gives value to the compound, instead of by arbitrary and technical names of no very definite meaning, such as *first proof*, *second proof*, &c.

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## CHAPTER I.

*On the researches relative to the specific gravities of alcoholic liquors, made by authority of European governments, or by private persons, for scientific purposes.*

15. *For the British government, by Messrs. Gilpin and Blagden.* By far the most elaborate and accurate investigations ever published, in relation to the specific gravities of alcoholic liquors, are those to which this section refers. I have already stated briefly, in page 71 of my previous report, the reasons for the high degree of confidence to which the researches of these gentlemen are most justly entitled; but that it may fully appear, not only why they are to be regarded as exact, but also why I have seen fit to treat them as *standard results*, (except in a few particular instances,) I shall here give a complete account of these experiments, employing as much as possible the actual words used by Messrs. Gilpin and Blagden in their original papers, published in the Philosophical Transactions of the Royal Society, for the years 1790, 1792, and 1794.

16. This account will also serve to show that researches, intended for similar purposes and made under the authority of other governments, should not be performed roughly or by unskilful persons, if they are designed to become the basis of correct legislation with reference to the determination of the strengths and corresponding values of alcoholic liquors. For certainly, if all the toil, expense, and pains of several years' work, required by the researches of Messrs. Gilpin and Blagden, was considered, not only by the British government, but by the Royal Society, indispensable to avoid errors of considerable magnitude, it may well be inferred that a similar task is one of difficulty, and which demands skill, care, and labor on the part of the performer.

17. The researches of Messrs. Gilpin and Blagden were undertaken "in consequence of an application from government to Sir Joseph Banks, bart., president of the Royal Society, for the best means of ascertaining the just proportion of duty to be paid by any kind of spirituous liquor that should come before the officers of excise."

"The first step towards a right performance of the experiments was to procure water and alcohol as pure as possible. Distilled water is in all cases so nearly alike, that no difficulty occurred with regard to it; but the specific gravity of alcohol had been given so very differently by authors who had treated of it, that a particular set of experiments appeared necessary for determining to what degree of strength rectified spirits could conveniently be brought." These experiments were confided to Dr. Dollfuss, a Swiss chemist residing in London; several distillers also attempted to manufacture absolute alcohol; but the results were entirely unsuccessful. Messrs. Gilpin and Blagden, therefore, adopted alcohol of the specific gravity 0.825 at 60° Fahrenheit—water being unity at the same temperature—as a standard to which all other spirituous liquors might be referred.

18. "The mixtures were made by weight, as the only accurate method of fixing the proportions. A phial being provided of such size that it should be nearly full with the mixture, was made perfectly clean and dry, and being counterpoised, as much of the pure spirit as appeared necessary was poured into it. The weight of this spirit was then ascertained, and the weight of distilled water, required to make a mixture of the intended proportions, was calculated. This quantity of water was then added with all the necessary care; the last portions being put in by means of a well known instrument, which is composed of a small dish, terminating in a tube drawn to a fine point: the top of the dish being covered with the thumb, the liquor in it is prevented from running out through the tube by the pressure of the atmosphere, but instantly begins to issue by drops, or a very small stream, upon raising the thumb. Water being thus introduced into the phial, till it exactly counterpoised the weight, which, having been previously computed, was put into the opposite scale, the phial was shaken, and then well

stopped with its glass stopple, over which leather was tied very tight, to prevent evaporation. No mixture was used till it had remained in the phial at least a month, for the full penetration to have taken place; and it was always well shaken before it was poured out to have its specific gravity tried."

19. In the weighings which were made by Mr. Gilpin, "the vessel chosen as most convenient for the purpose was a hollow glass ball, terminating in a neck of a small bore. As the balance was so extremely accurate, it was thought expedient to use one of only 2,965 grains capacity, as admitting the heat of any fluid contained in it to be more nicely determined. The ball of this vessel, which may be called the weighing bottle, measured about 2.8 inches in diameter, and was spherical, except a slight flattening on the part opposite to the neck, which served as a bottom for it to stand upon. Its neck was formed of a portion of a barometer tube .25 of an inch in bore and about 1½ inch long; it was perfectly cylindrical, and on its outside, very near the middle of its length, a fine circle or ring was cut round it with a diamond, as the mark to which it was to be filled with the liquor. This mark was made by fixing the bottle in a lathe, and turning it round with great care in contact with the diamond. The glass of this bottle was not very thick; it weighed 916 grains, and, with its silver cap, 936.

"When the specific gravity of a liquor was to be taken by means of this bottle, the liquor was first brought nearly to the required temperature, and then the bottle was filled with it up to the beginning of the neck only, that there might be room for shaking it. A very fine and sensible thermometer was then passed through the neck of the bottle into the contained liquor, which showed whether it was above or below the intended temperature. In the former case the bottle was brought into colder air, or even plunged for a moment in cold water; the thermometer in the mean time being frequently put into the contained liquor, till it was found to sink to the right point. In like manner, when the liquor was too cold the bottle was brought into warmer air, immersed in warm water, or more commonly held between the hands, till upon repeated trials with the thermometer the just temperature was found. It will be understood that during the course of this heating or cooling, the bottle was very frequently shaken between each immersion of the thermometer; and the top of the neck was kept covered, either with the finger, or a silver cap made on purpose, as constantly as possible. Hot water was used to raise the temperature only in heats of 80° and upwards, inferior heats being obtained by applying the hands to the bottle. When the hot water was employed, the ball of the bottle was plunged into it and again quickly lifted out, with the necessary shaking interposed, as often as was necessary for communicating the required heat to the liquor; but care was taken to wipe the bottle dry after each immersion, before it was shaken, lest any adhering moisture might by accident get into it. The liquor having, by these means, been brought to the desired tem-

perature, the next operation was to fill up the bottle exactly to the mark upon the neck, which was done with some of the same liquor, by means of a glass funnel with a very small bore. Mr. Gilpin endeavored to get that portion of the liquor which was employed for this purpose, pretty nearly to the temperature of the liquor contained in the bottle; but as the whole quantity to be added never exceeded ten grains, a difference of ten degrees in the heat of that small quantity, which is more than it ever amounted to, would have occasioned an error of only $\frac{1}{30}$ of a degree in the temperature of the mass. Enough of the liquor was put in to fill the neck rather above the mark, and the superfluous quantity was then absorbed to great nicety, by bringing into contact with it the fine point of a small roll of blotting paper. As the surface of the liquor in the neck would be always concave, the bottom or centre of this concavity was the part made to coincide with the mark round the glass; and in viewing it, care was taken that the near and opposite sides of the mark should appear exactly in the same line, by which means all parallax was avoided. A silver cap, which fitted tight, was then put upon the neck to prevent evaporation; and the whole apparatus was, in that state, laid in the scale of the balance, to be weighed with all the exactness possible.

"20. The spirit employed by Mr. Gilpin was furnished to him by Dr. Dollfuss, under whose inspection it had been rectified from rum supplied by government. Its specific gravity at 60 degrees of heat was .82514. It was first weighed pure, in the above mentioned bottle, at every five degrees of heat from 30° to 100° inclusively. Then mixtures were formed of it and distilled water, in every proportion from $\frac{1}{11}$th of water to equal parts of water and spirit; the quantity of water added being successively augmented, in the proportion of five grains to one hundred of the spirit; and these mixtures were also weighed in the bottle, like the pure spirit, at every 5 degrees of heat. The numbers hence resulting are given in Table I., where the first column shows the degrees of heat; the second gives the weight of the pure spirit contained in the bottle at those different degrees; the third gives the weight of a mixture in the proportions of 100 parts by weight of that spirit to 5 of water; and so on successively till the water and the spirit are in equal parts. The bottle itself, with its cap, having been previously counterpoised, these numbers are the weights of the liquor contained in it in grains and hundredths of a grain. They are the mean of three several experiments at least, as Mr. Gilpin always filled and weighed the bottle over again that number of times, if not oftener. The heat was taken at the even degree, as shown by the thermometer, without any allowance in the first instance, because the coincidence of the mercury with a division can be perceived more accurately than any fraction can be estimated; and the errors of the thermometers, if any, it was supposed would be less upon the grand divisions of 5 degrees than in any others. It must be observed, that Mr. Gilpin used the same mixture throughout all the different temperatures, heating it up from 30° to 100°; hence some small error in its strength may have been occasioned,

in the higher degrees, by more spirit evaporating than water; but this, it is believed, must have been trifling, and greater inconvenience would probably have resulted from interposing a fresh mixture.

21. " In order to deduce the specific gravities from the numbers in the annexed table, it was necessary to weigh distilled water in the same vessel.

## TABLE I.

*Weights in grains at different temperatures.*

| Temperature. | Weight of water. | Weight of pure spirit. | 100 grains spirit combined with weights of water. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 100 + 5 | 100 + 10 | 100 + 15 | 100 + 20 | 100 + 25 | 100 + 30 | 100 + 35 |
| ° | | | | | | | | | |
| 30 | ..... | 2487.32 | 2519.98 | 2548.59 | 2573.86 | 2596.65 | 2617.24 | 2636.16 | 2653.54 |
| 35 | 2967.03 | 80.79 | 13.48 | 41.96 | 67.34 | 90.15 | 10.80 | 2629.77 | 47.30 |
| 40 | 67.34 | 74.18 | 06.98 | 35.52 | 60.83 | 83.70 | 04.50 | 23.42 | 41.02 |
| 45 | 67.29 | 67.52 | 00.33 | 28.90 | 54.24 | 77.16 | 2597.99 | 17.04 | 34.68 |
| 50 | 66.97 | 60.77 | 2493.48 | 2522.10 | 2547.61 | 2570.61 | 91.50 | 10.59 | 2628.26 |
| 55 | 66.39 | 53.84 | 86.51 | 15.30 | 40.88 | 63.94 | 84.79 | 04.07 | 21.77 |
| 60 | 2965.39 | 2446.86 | 79.75 | 08.60 | 34.19 | 57.23 | 78.22 | 2597.50 | 15.26 |
| 65 | 64.17 | 40.04 | 72.97 | 01.87 | 27.51 | 50.56 | 71.48 | 90.86 | 08.72 |
| 70 | 62.72 | 33.37 | 2466.28 | 2495.00 | 2520.65 | 2543.84 | 2564.89 | 84.23 | 02.14 |
| 75 | 61.03 | 26.47 | 59.18 | 88.03 | 13.63 | 36.91 | 58.14 | 77.47 | 2595.43 |
| 80 | 2959.13 | 2419.18 | 51.95 | 80.83 | 06.61 | 29.85 | 51.10 | 2570.52 | 88.61 |
| 85 | 57.03 | 12.02 | 2444.80 | 73.68 | 2499.59 | 23.08 | 44.41 | 63.80 | 81.91 |
| 90 | 54.80 | 04.92 | 37.72 | 66.64 | 92.62 | 16.20 | 37.57 | 56.95 | 75.20 |
| 95 | 52.20 | 2397.75 | 30.56 | 59.51 | 85.51 | 09.15 | 30.51 | 49.95 | 68.18 |
| 100 | 2949.36 | 90.64 | 2423.53 | 2452.63 | 2478.59 | 2502.15 | 2523.59 | 2543.08 | 2561.28 |

## TABLE I—Continued.

*Weights in grains at different temperatures.*

| Temperature. | 100 grains spirit combined with successive weights of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 + 40 | 100 + 45 | 100 + 50 | 100 + 55 | 100 + 60 | 100 + 65 | 100 + 70 |
| ° | | | | | | | |
| 30 | 2669.64 | 2684.63 | 2698.41 | 2711.19 | 2723.00 | 2733.84 | 2744.19 |
| 35 | 63.48 | 78.43 | 92.32 | 2705.08 | 16.96 | 27.78 | 38.24 |
| 40 | 57.35 | 72.37 | 86.37 | 2699.09 | 11.02 | 21.90 | 32.45 |
| 45 | 50.96 | 66.13 | 80.25 | 92.97 | 04.82 | 15.98 | 26.38 |
| 50 | 2644.68 | 2659.95 | 2674.04 | 86.81 | 2698.63 | 09.92 | 2720.37 |
| 55 | 38.25 | 53.55 | 67.72 | 80.57 | 92.44 | 03.67 | 14.27 |
| 60 | 31.82 | 47.20 | 61.45 | 74.31 | 86.16 | 2697.44 | 08.18 |
| 65 | 25.41 | 40.80 | 55.09 | 2667 97 | 80.00 | 91.22 | 01.99 |
| 70 | 2618.89 | 34.30 | 48.65 | 61.67 | 73.68 | 85.02 | 2695.66 |
| 75 | 12.20 | 2627.78 | 2642.17 | 55.19 | 2667.32 | 2678.60 | 89.34 |
| 80 | 05.32 | 21.03 | 35.47 | 2648.47 | 60.69 | 72.02 | 82.77 |
| 85 | 2598.76 | 14.48 | 28.87 | 41.85 | 51.19 | 65.54 | 76.40 |
| 90 | 92.17 | 07.86 | 22.30 | 35.38 | 47.61 | 59.07 | 70.09 |
| 95 | 85.12 | 01.12 | 15.70 | 28.83 | 41.10 | 52.56 | 63.64 |
| 100 | 2578.37 | 2594.45 | 2609.11 | 2622.22 | 2634.38 | 2645.95 | 2657.14 |

## TABLE I—Continued.

*Weights in grains at different temperatures.*

| Temperature. | 100 grains spirit combined with weights of water. | | | | | |
|---|---|---|---|---|---|---|
| | 100 + 75 | 100 + 80 | 100 + 85 | 100 + 90 | 100 + 95 | 100 + 100 |
| 30° | 2753.67 | 2762.61 | 2771.26 | 2779.21 | 2786.47 | 2793.26 |
| 35 | 47.90 | 56.97 | 65.47 | 73.53 | 80.75 | 87.59 |
| 40 | 42.18 | 51.35 | 59.85 | 67.78 | 75.15 | 82.06 |
| 45 | 36.21 | 45.47 | 54.13 | 62.03 | 69.55 | 76.40 |
| 50 | 2730.27 | 2739.52 | 2748.22 | 2756.25 | 2763.67 | 2770.62 |
| 55 | 24.20 | 33.47 | 42.25 | 50.32 | 57.82 | 64.72 |
| 60 | 18.26 | 27.56 | 36.26 | 44.32 | 51.87 | 58.82 |
| 65 | 12.06 | 21.47 | 30.27 | 38.35 | 45.93 | 52.82 |
| 70 | 05.87 | 2715.40 | 2724.22 | 32.42 | 40.00 | 46.88 |
| 75 | 2699.57 | 09.08 | 17.95 | 2726.25 | 2733.92 | 2740.83 |
| 80 | 93.03 | 02.57 | 11.50 | 19.78 | 27.49 | 34.49 |
| 85 | 86.77 | 2696.33 | 05.37 | 13.69 | 21.47 | 28.60 |
| 90 | 80.60 | 90.22 | 2699.10 | 07.44 | 15.22 | 22.32 |
| 95 | 74.20 | 83.79 | 92.81 | 01.18 | 08.91 | 16.04 |
| 100 | 2667.61 | 2677.25 | 2686.36 | 2694.76 | 2702.50 | 2709.75 |

22. In computing the specific gravities from the results of table 1, "the expansion of hollow glass was taken from General Roy's experiments in the LXXVth volume of the Philosophical Transactions, as .0000517 of an inch upon a foot for every degree of heat; whence its effect, in enlarging the capacity of a sphere, was computed, and the resulting correction added to the weight of the liquors in heats below 60°, and subtracted from it in heats above."

"Another correction also became necessary, on account of a part of the stem of the thermometer, which was not immersed in the liquor. This instrument, made by Ramsden, had its ball .22 of an inch in diameter, and its stem 13 inches in length. From the ball to the commencement of the scale, 3.6 inches of the stem were bare, and then the scale began, which reached from 15 to 110 degrees. The part of it particularly made use of in these experiments, namely, from 30° to 100°, measured 6.82 inches. The scale was made of ivory, and carried divisions to every fifth of a degree, the quarters of which could be readily estimated; so that the instrument could be read off to twentieths of a degree. When the thermometer was immersed in the weighing bottle, the liquor reached up nearly to what would have been 0° upon its stem; hence, as the heat of the room in which the experiments were made remained about 60°, the correction for the different heat of the quicksilver in the stem from that in the ball of the thermometer was calculated according to Mr. Cavendish's table, given in the LXVIIth volume of the Philosophical Transactions. Thus the real heat of the fluid in the weighing bottle being found, an allowance was made to reduce it to the exact degree indicated on the scale of the thermometer."

23. "The precise specific gravity of the pure spirit employed was .82514; but, to avoid an inconvenient fraction, it was taken in constructing table 2, of specific gravities, as .825 only, a proportionable deduction being made from all the other numbers. Thus the following table gives the true specific gravity at the different degrees of heat, of a pure rectified spirit, whose specific gravity, at 60°, is 0.825, together with the specific gravities of different mixtures of it with water, at those different temperatures, as far as equal parts by weight."

## TABLE II.

*Specific gravities at different temperatures.*

| Temperature. | Distilled water. | Pure spirit. | 100 grains of spirit combined with weights of water. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 100 + 5 | 100 + 10 | 100 + 15 | 100 + 20 | 100 + 25 | 100 + 30 | 100 + 35 |
| 30° | ..... | .83899 | .85001 | .85967 | .86819 | .87589 | .88284 | .88922 | .89509 |
| 35 | 1.00087 | 673 | .84776 | 737 | 592 | 363 | 061 | 700 | 292 |
| 40 | 1.00091 | 445 | 551 | 515 | 367 | 140 | .87843 | 481 | 074 |
| 45 | 1.00084 | 215 | 321 | 286 | 140 | .86913 | 617 | 260 | .88855 |
| 50 | 1.00066 | .82981 | 084 | 051 | .85910 | 688 | 392 | 036 | 632 |
| 55 | 1.00040 | 741 | .83843 | .84815 | 677 | 455 | 159 | .87809 | 406 |
| 60 | 1.00000 | 500 | 609 | 583 | 445 | 223 | .86931 | 582 | 181 |
| 65 | .99952 | 262 | 374 | 350 | 213 | .85991 | 698 | 352 | .87954 |
| 70 | .99896 | 032 | 142 | 111 | .84975 | 758 | 469 | 121 | 725 |
| 75 | .99832 | .81792 | .82896 | .83869 | 731 | 517 | 234 | .86886 | 491 |
| 80 | .99762 | 543 | 649 | 623 | 491 | 276 | .85993 | 648 | 258 |
| 85 | .99685 | 291 | 396 | 371 | 243 | 036 | 757 | 411 | 021 |
| 90 | .99602 | 044 | 150 | 126 | 001 | .84797 | 518 | 172 | .86787 |
| 95 | .99507 | .80794 | .81900 | .82877 | .83753 | 550 | 272 | .85928 | 542 |
| 100 | .99404 | 548 | 657 | 639 | 513 | 308 | 031 | 688 | 302 |

## TABLE II.—Continued.

*Specific gravities at different temperatures.*

| Temperature. | 100 grains of spirit combined with weights of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 + 40 | 100 + 45 | 100 + 50 | 100 + 55 | 100 + 60 | 100 + 65 | 100 + 70 |
| 30° | .90053 | .90558 | .91023 | .91454 | .91853 | .92219 | .92568 |
| 35 | .89839 | 343 | .90811 | 242 | 644 | 009 | 362 |
| 40 | 626 | 133 | 605 | 034 | 438 | .91805 | 161 |
| 45 | 405 | .89916 | 393 | .90822 | 222 | 599 | .91950 |
| 50 | 187 | 702 | 177 | 608 | 007 | 388 | 740 |
| 55 | .88963 | 479 | .89957 | 390 | .90791 | 170 | 528 |
| 60 | 740 | 259 | 741 | 173 | 570 | .90954 | 316 |
| 65 | 518 | 037 | 518 | .89952 | 359 | 738 | 100 |
| 70 | 291 | .88810 | 294 | 733 | 136 | 522 | .90880 |
| 75 | 058 | 585 | 068 | 507 | .89916 | 298 | 660 |
| 80 | .87822 | 352 | .88839 | 277 | 690 | 072 | 435 |
| 85 | 590 | 120 | 605 | 043 | 460 | .89843 | 209 |
| 90 | 360 | .87889 | 376 | .88817 | 230 | 617 | .89988 |
| 95 | 114 | 654 | 146 | 588 | 003 | 390 | 763 |
| 100 | .86879 | 421 | .87915 | 357 | .88769 | 158 | 536 |

## TABLE II.—Continued.

*Specific gravities at different temperatures.*

| Temperature. | 100 grains of spirit combined with weights of water. | | | | | |
|---|---|---|---|---|---|---|
| | 100 + 75 | 100 + 80 | 100 + 85 | 100 + 90 | 100 + 95 | 100 + 100 |
| 30 | .92888 | .93191 | .93483 | .93751 | .93996 | .94225 |
| 35 | 687 | .9299ɔ | 281 | 553 | 796 | 027 |
| 40 | 489 | 799 | 086 | 353 | 602 | .93835 |
| 45 | 281 | 595 | .92887 | 153 | 407 | 638 |
| 50 | 075 | 388 | 681 | .92952 | 202 | 436 |
| 55 | .91863 | 176 | 472 | 744 | .92997 | 230 |
| 60 | 656 | .91971 | 264 | 536 | 791 | 025 |
| 65 | 440 | 769 | 055 | 328 | 584 | .92816 |
| 70 | 225 | 547 | .91845 | 121 | 377 | 608 |
| 75 | 005 | 326 | 625 | .91909 | 164 | 397 |
| 80 | .90780 | 103 | 404 | 683 | .91943 | 179 |
| 85 | 558 | .90882 | 186 | 465 | 729 | .91969 |
| 90 | 342 | 663 | .90967 | 248 | 511 | 751 |
| 65 | 119 | 443 | 747 | 029 | 290 | 531 |
| 100 | .89889 | 215 | 522 | .90805 | 066 | 310 |

24. In justification of their adoption of the above described method for determining the specific gravities in preference to that of weighing an immersed body, Messrs. Gilpin & Blagden assign the following reasons: "When a ball of glass, which is the properest kind of solid body, is weighed in any spirituous or watery fluid, the adhesion of the fluid occasions some inaccuracy, and renders the balance comparatively sluggish. To what degree this effect proceeds, is uncertain; but, from some experiments made by Mr. Gilpin, with that view, it appears to be very sensible. Moreover, in this method a large surface must be exposed to the air during the operation of weighing, which, especially in the higher temperatures, would give occasion to such an evaporation as to alter essentially the strength of the mixture. It seemed, also, as if the temperature of the fluid under trial could be determined more exactly in the method of filling a vessel than in the other; for the fluid cannot well be stirred while the ball to be weighed remains immersed in it; and as some time must necessarily be spent in the weighing, the change of heat which takes place during that period will be unequal through the mass, and may occasion a sensible error. It is true, on the other hand, that in the method of filling a vessel, the temperature could not be ascertained with the utmost precision, because the neck of the vessel employed, containing about ten grains, was filled up to the mark with spirit not exactly of the same temperature, as will be explained presently; but this error, it is supposed, would by no means equal the other; and the utmost quantity of it may be estimated very nearly. Finally, it was much easier to bring the fluid to any given temperature, when it was in a vessel to be weighed; than when it was to have a solid body weighed in it; because, in the former case, the quantity was smaller, and the vessel containing it more manageable, being readily heated with the hand or warm water, and cooled with cold water; and the very circumstance that so much of the fluid was not required, proved a material convenience. The particular disadvantage in the method of weighing in a vessel, is the difficulty of filling it with extreme accuracy; but when the vessel is judiciously and neatly marked, the error of filling will, with due care, be exceedingly minute. By several repetitions of the same experiment, Mr. Gilpin seemed to bring it within the $\frac{1}{1000}$th part of the whole weight."

"Perhaps some persons may object to the preceding experiments on account of the small quantities mixed and weighed. Undoubtedly, experiments on a large scale have some advantages, but these, in general, depend more on the coarseness of tools, and clumsiness of operators, than on the nature of the operations. If instruments be exceedingly exact, and the experimenter equal to the task of using them properly, the errors upon moderate quantities will be quite as small in proportion as upon large; and, in this particular instance, when the greatest source of error lay in the determination of the heat, the smaller quantities had, in that respect, an evident advantage; it being much easier to bring six ounces of a liquor to an uniform temperature than so many gallons. One of our most

essential instruments, namely, the balance, was so much superior in nicety to anything that could be wanted in these experiments, that error in weighing must be thrown entirely out of the question. It was constructed by Mr. Ramsden; and some account, though very imperfect, of its admirable mechanism, as well as of its extreme sensibility, even when loaded with considerable weights, has been given in the 23d volume of the Journal de Physique."

25. Two years after the report had been published, from which the above extracts have been made, Messrs. Blagden & Gilpin made a second or supplementary report.* In this it is stated, that the first report having been "drawn up, when the experiments had been continued only to equal quantities of alcohol and water, it was foreseen that a further set of experiments, on more dilute liquors, would be wanted; but, as these must necessarily take up a considerable time, the persons concerned thought it best to submit those already made to the public; that if errors or inaccuracies should be discovered they might be avoided, and if any person should suggest a better method it might be adopted in the subsequent proceedings. As no censure had yet been passed on our former experiments, the same general method was pursued for the new series; with a small variation, however, the reason of which is now to be explained."

"In the report on the first experiments, the following remark is introduced: 'It must be observed that Mr. Gilpin used the same mixture throughout all the different temperatures, heating it up from 30° to 100°; hence, some small error in its strength may have been occasoned in the higher degrees, by more spirit evaporating than water; but this, it is believed, must have been trifling, and greater inconvenience would probably have resulted from interposing a fresh mixture.' The consciousness that such a source of error existed, made us desirous of ascertaining to what quantity it amounted, by some previous experiments, before the new set should be begun. These showed that it was somewhat greater than had been supposed, though not such as ever to cause a difference of more than a single unit in the third place of decimals, even in the temperature of 100°. The greatest difference found in that degree of heat was .00094; and in a heat of 80°, the highest to which the tables for use were to be carried, it amounted only to 0.00064; being in both cases greatest when the mixture consisted of 85 parts of water, by weight, to 100 of alcohol. This difference, however, small as it was, afforded sufficient reason for repeating all the former experiments, conjointly with the new set for dilute spirits, so as to make one entire series with the same spirit, and executed throughout in an uniform manner. To obviate the error from evaporation in this series, and ascertain what each mixture really lost of its strength during the operation, all the fluids were first weighed at 60° before they were cooled down to 30°; from

* Phil. Trans., 1792, p. 425.

30° to 100° they were weighed at every 5 degrees, as before, consequently a second time at 60°; and lastly, after having been heated to 100°, they were again brought to 60°, and weighed at that point a third time. The difference between these weights, at the beginning, middle, and end of the experiment, was applied, in due proportion, to correct the numbers of the respective intervals between them; by which means it is believed that the error arising from the gradual evaporation of the spirit, during the experiment, has been made to disappear. Mr. Gilpin, having also observed that the spirits adhering to the sides of the funnel which he employed to fill up the weighing bottle grew weak by the evaporation, and so diluted the fresh spirit poured into the funnel, determined to use a smaller instrument of this kind, namely, such an one as would not hold more than 15 grains of spirit; in which, a less surface being left wet when the spirit ran out, the error from this cause would be proportionably diminished."

26. "Under all these precautions were the experiments made, of which the results are given in the following tables. They are drawn up exactly like the tables in the former report; but, as alcohol was taken for the fixed quantity in the first half, so water is taken for the fixed quantity in the last half; which, therefore, consists of mixtures containing all 100 grains of water, with 95 grains, 90, 85, and so on successively of alcohol, till the last column is pure water. This arrangement will be clear to every one on reading the title of each column of the tables. The first table gives the actual weights at the even degree of the thermometer, corrected for the evaporation; and the second table gives the specific gravities, calculated from those weights, with the same allowances and corrections as were specified in the original report."

## TABLE III.

*Weights in grains at different temperatures.*

| Temperature. | Pure spirit. | 100 grains of spirit combined with weights of water. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 100 + 5 | 100 + 10 | 100 + 15 | 100 + 20 | 100 + 25 | 100 + 30 |
| 30° | 2487.35 | 2519.92 | 2548.42 | 2573.80 | 2596.66 | 2617.30 | 2636.23 |
| 35 | 80.87 | 13.43 | 41.84 | 67.26 | 90.16 | 10.87 | 29.92 |
| 40 | 74.30 | 06.75 | 35.41 | 60.74 | 83.66 | 04.50 | 23.56 |
| 45 | 67.62 | 00.14 | 28.75 | 54.09 | 77.10 | 2597.98 | 17.03 |
| 50 | 2460.75 | 2493.33 | 2521.96 | 2547.47 | 2570.42 | 91.38 | 10.54 |
| 55 | 53.80 | 86.37 | 15.03 | 40.60 | 63.64 | 84.65 | 03.80 |
| 60 | 47.00 | 79.56 | 08.27 | 33.83 | 56.90 | 77.95 | 2597.22 |
| 65 | 40.12 | 72.75 | 01.53 | 26.99 | 50.22 | 71.24 | 90.55 |
| 70 | 33.23 | 65.88 | 2494.56 | 2520.03 | 43.32 | 2564.47 | 83.88 |
| 75 | 2426.23 | 2458.78 | 87.62 | 13.08 | 2536.39 | 57.61 | 2576.93 |
| 80 | 19.02 | 51.67 | 80.45 | 06.08 | 29.24 | 50.50 | 69.86 |
| 85 | 11.92 | 44.63 | 73.33 | 2499.01 | 22.29 | 43.54 | 63.01 |
| 90 | 04.90 | 37.62 | 66.32 | 91.99 | 15.28 | 36.63 | 56.11 |
| 95 | 2397.68 | 30.33 | 59.13 | 84.74 | 08.10 | 29.46 | 49.13 |
| 100 | 90.60 | 2423.22 | 2452.13 | 2477.64 | 2500.91 | 2522.30 | 2541.92 |

## TABLE III—Continued.

*Weights in grains at different temperatures.*

| Temperature. | 100 grains of spirit combined with successive weights of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 + 35 | 100 + 40 | 100 + 45 | 100 + 50 | 100 + 55 | 100 + 60 | 100 + 65 |
| ° | | | | | | | |
| 30 | 2653.73 | 2669.83 | 2684.74 | 2698.51 | 2711.14 | 2722.89 | 2733.87 |
| 35 | 47.47 | 63.64 | 78.60 | 92.43 | 05.14 | 16.92 | 27.87 |
| 40 | 41.08 | 57.23 | 72.30 | 86.32 | 2698.94 | 10.81 | 21.83 |
| 45 | 34.64 | 50.87 | 66.04 | 79.99 | 92.77 | 04.57 | 15.62 |
| 50 | 28.21 | 44.43 | 59.55 | 73.64 | 86.54 | 2698.42 | 09.48 |
| 55 | 2621.50 | 37.86 | 2653.04 | 2667.14 | 79.98 | 91.83 | 02.98 |
| 60 | 15.03 | 2631.37 | 46.53 | 60.62 | 2673.55 | 85.52 | 2696.73 |
| 65 | 08.37 | 24.75 | 40.01 | 54.04 | 67.07 | 79.15 | 90.32 |
| 70 | 01.67 | 17.96 | 33.32 | 47.52 | 60.63 | 72.74 | 84.02 |
| 75 | 2594.80 | 11.19 | 2626.55 | 2640.81 | 53.99 | 2666.06 | 77.34 |
| 80 | 87.93 | 04.29 | 19.72 | 33.99 | 2647.12 | 59.36 | 2670.69 |
| 85 | 80.93 | 2597.45 | 13.02 | 27.39 | 40.60 | 52.78 | 64.16 |
| 90 | 74.02 | 90.60 | 06.16 | 20.52 | 33.74 | 46.00 | 57.41 |
| 95 | 67.03 | 83.65 | 2599.24 | 13.57 | 26.94 | 39.25 | 50.63 |
| 100 | 2559.96 | 2576.56 | 92.14 | 2606.50 | 2619.75 | 2632.17 | 2643.75 |

## TABLE III—Continued.

*Weights in grains at different temperatures.*

| Temperature | 100 grains of spirit combined with successive weights of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 + 70 | 100 + 75 | 100 + 80 | 100 + 85 | 100 + 90 | 100 + 95 | 100 + 100 |
| ° | | | | | | | |
| 30 | 2744.20 | 2753.75 | 2762.72 | 2771.08 | 2778.99 | 2786.36 | 2793.22 |
| 35 | 38.13 | 47.74 | 56.91 | 65.32 | 73.22 | 80.59 | 87.54 |
| 40 | 32.24 | 41.86 | 50.96 | 59.50 | 67.48 | 74.90 | 81.84 |
| 45 | 26.09 | 35.77 | 44.82 | 53.36 | 61.42 | 68.85 | 75.94 |
| 50 | 2719.93 | 2729.64 | 2738.74 | 2747.27 | 2755.37 | 2762.95 | 2770.14 |
| 55 | 13.60 | 23.51 | 32.64 | 41.24 | 49.27 | 56.83 | 64.09 |
| 60 | 07.40 | 17.30 | 26.52 | 35.17 | 43.28 | 50.93 | 58.17 |
| 65 | 01.05 | 10.96 | 20.25 | 28.98 | 37.09 | 44.86 | 52.21 |
| 70 | 2691.76 | 04.64 | 13.87 | 2722.75 | 2730.94 | 2738.73 | 2746.06 |
| 75 | 88.14 | 2698.07 | 2707.49 | 16.35 | 24.64 | 32.39 | 39.89 |
| 80 | 81.50 | 91.50 | 00.94 | 09.76 | 18.12 | 26.06 | 33.53 |
| 85 | 74.95 | 84.98 | 2694.53 | 03.33 | 11.86 | 19.74 | 27.25 |
| 90 | 68.29 | 78.49 | 87.99 | 2696.91 | 05.37 | 13.32 | 21.01 |
| 95 | 61.51 | 71.82 | 81.34 | 90.33 | 2698.86 | 06.88 | 14.61 |
| 100 | 2654.76 | 2664.99 | 2674.62 | 2683.63 | 92.25 | 2700.33 | 2708.04 |

## TABLE III—Continued.

*Weights in grains at different temperatures.*

| Temperature. | Successive weights of spirit combined with 100 grains of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 95 + 100 | 90 + 100 | 85 + 100 | 80 + 100 | 75 + 100 | 70 + 100 | 65 + 100 |
| 30° | 2799.85 | 2806.61 | 2813.85 | 2821.35 | 2828.90 | 2836.39 | 2844.16 |
| 35 | 94.19 | 01.14 | 08.52 | 16.07 | 23.68 | 31.36 | 39.26 |
| 40 | 88.69 | 2795.70 | 03.17 | 10.73 | 18.36 | 26.31 | 34.40 |
| 45 | 82.99 | 89.99 | 2797.45 | 05.08 | 12.93 | 21.00 | 29.28 |
| 50 | 2777.19 | 2784.30 | 91.72 | 2799.58 | 07.56 | 15.71 | 2824.12 |
| 55 | 71.29 | 78.54 | 85.96 | 93.82 | 01.89 | 10.23 | 18.80 |
| 60 | 65.40 | 72.70 | 80.26 | 88.25 | 2796.45 | 04.85 | 13.65 |
| 65 | 59.47 | 66.73 | 2774.43 | 82.62 | 90.81 | 2799.38 | 08.31 |
| 70 | 2753.41 | 2760.75 | 68.45 | 2776.72 | 85.06 | 93.80 | 02.88 |
| 75 | 47.23 | 54.73 | 62.58 | 70.93 | 79.26 | 88.00 | 2797.21 |
| 80 | 40.93 | 48.42 | 56.43 | 61.87 | 2773.33 | 2782.14 | 91.52 |
| 85 | 34.80 | 42.31 | 50.22 | 58.80 | 67.44 | 76.33 | 85.81 |
| 90 | 28.59 | 36.23 | 44.24 | 52.76 | 61.51 | 70.59 | 80.11 |
| 95 | 22.23 | 29.89 | 37.98 | 46.57 | 55.34 | 64.57 | 74.25 |
| 100 | 2715.73 | 2723.35 | 2731.07 | 2740.43 | 2749.28 | 2758.48 | 2768.43 |

## TABLE III—Continued.

*Weights in grains at different temperatures.*

| Temperature. | Successive weights of spirit combined with 100 grains of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 60 + 100 | 55 + 100 | 50 + 100 | 45 + 100 | 40 + 100 | 35 + 100 | 30 + 100 |
| ° | | | | | | | |
| 30 | 2852.03 | 2859.71 | 2867.12 | 2874.43 | 2881.34 | 2887.77 | 2894.22 |
| 35 | 47.45 | 55.32 | 63.16 | 70.87 | 78.21 | 85.06 | 92.07 |
| 40 | 42.62 | 50.88 | 59.06 | 67.08 | 74.81 | 82.30 | 89.78 |
| 45 | 37.64 | 46.16 | 54.67 | 63.04 | 71.22 | 79.22 | 87.33 |
| 50 | 32.76 | 41.52 | 50.29 | 58.96 | 67.52 | 75.98 | 84.57 |
| 55 | 2827.68 | 2836.69 | 2845.72 | 2854.75 | 2863.75 | 2872.67 | 2881.69 |
| 60 | 22.65 | 31.90 | 41.10 | 50.50 | 59.87 | 69.15 | 78.72 |
| 65 | 17.49 | 26.90 | 36.30 | 45.97 | 55.65 | 65.45 | 75.49 |
| 70 | 12.16 | 21.78 | 31.61 | 41.42 | 51.53 | 61.63 | 72.06 |
| 75 | 06.75 | 2816.63 | 2826.56 | 2836.80 | 2847.14 | 2857.70 | 2868.49 |
| 80 | 01.25 | 11.23 | 21.38 | 31.92 | 42.56 | 53.38 | 64.54 |
| 85 | 2795.69 | 05.85 | 16.32 | 27.12 | 38.07 | 49.28 | 60.86 |
| 90 | 90.13 | 00.40 | 11.05 | 22.15 | 33.38 | 44.81 | 56.80 |
| 95 | 84.36 | 2794.91 | 05.79 | 17.08 | 28.46 | 40.26 | 52.47 |
| 100 | 2778.64 | 89.32 | 2800.25 | 2811.80 | 2823.55 | 2835.30 | 2848.18 |

## TABLE III—Continued.

*Weights in grains at different temperatures.*

| Temperature. | Successive weights of spirit combined with 100 grains of water. | | | | | Water. |
|---|---|---|---|---|---|---|
| | 25 + 100 | 20 + 100 | 15 + 100 | 10 + 100 | 5 + 100 | |
| 30° | 2900.85 | 2908.21 | 2917.19 | 2928.80 | 2944.53 | ..... |
| 35 | 2899.31 | 07.45 | 16.95 | 28.98 | 45.02 | 2967.14 |
| 40 | 97.61 | 06.39 | 16.41 | 28.93 | 45.25 | 67.45 |
| 45 | 95.67 | 04.98 | 15.55 | 28.49 | 45.20 | 67.40 |
| 50 | 93.58 | 03.39 | 14.42 | 2927.81 | 2944.73 | 67.05 |
| 55 | 91.11 | 01.42 | 13.02 | 26.73 | 43.98 | 66.34 |
| 60 | 2888.62 | 2899.35 | 2911.32 | 25.50 | 42.98 | 2965.39 |
| 65 | 85.85 | 97.09 | 09.43 | 23.90 | 41.69 | 64.11 |
| 70 | 82.90 | 94.56 | 07.33 | 2922.24 | 2940.13 | 62.66 |
| 75 | 79.67 | 91.79 | 05.04 | 20.17 | 38.33 | 60.97 |
| 80 | 2876.22 | 2888.73 | 02.35 | 17.83 | 36.31 | 2959.07 |
| 85 | 72.88 | 85.56 | 2899.55 | 15.46 | 34.14 | 56.94 |
| 90 | 69.16 | 82.25 | 96.58 | 12.84 | 31.77 | 54.70 |
| 95 | 65.15 | 78.71 | 93.44 | 10.02 | 29.15 | 52.08 |
| 100 | 2861.12 | 2875.07 | 2890.04 | 2906.97 | 2926.28 | 2949.34 |

## TABLE IV.

*Specific gravities at different temperatures.*

| Temperature. | Pure spirit. | 100 grains spirit combined with weights of water. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 100 + 5 | 100 + 10 | 100 + 15 | 100 + 20 | 100 + 25 | 100 + 30 |
| ° | | | | | | | |
| 30 | .83896 | .84995 | .85957 | .86825 | .87585 | .88282 | .88921 |
| 35 | 672 | 769 | 729 | 587 | 357 | 059 | 701 |
| 40 | 445 | 539 | 507 | 361 | 134 | .87838 | 481 |
| 45 | 214 | 310 | 277 | 131 | .86907 | 613 | 255 |
| 50 | .82977 | 076 | 042 | .85902 | 676 | 384 | 030 |
| 55 | 736 | .83834 | .84802 | 664 | 441 | 150 | .87796 |
| 60 | 500 | 599 | 568 | 430 | 208 | .86918 | 568 |
| 65 | 262 | 362 | 334 | 193 | .85976 | 686 | 337 |
| 70 | 023 | 124 | 092 | .84951 | 736 | 451 | 105 |
| 75 | .81780 | .82878 | .83851 | 710 | 493 | 212 | .86864 |
| 80 | 530 | 631 | 603 | 467 | 248 | .85966 | 623 |
| 85 | 283 | 386 | 355 | 221 | 006 | 723 | 380 |
| 90 | 039 | 142 | 111 | .83977 | .84762 | 483 | 139 |
| 95 | .80788 | .81888 | .82860 | 724 | 511 | 232 | .85896 |
| 100 | 543 | 643 | 618 | 478 | 262 | .84984 | 646 |

## TABLE IV—Continued.

*Specific gravities at different temperatures.*

| Temperature. | 100 grains of spirit combined with successive weights of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 + 35 | 100 + 40 | 100 + 45 | 100 + 50 | 100 + 55 | 100 + 60 | 100 + 65 |
| ° | | | | | | | |
| 30 | .89511 | .90054 | .90558 | .91023 | .91449 | .91847 | .92217 |
| 35 | 294 | .89839 | 345 | .90811 | 241 | 640 | 009 |
| 40 | 073 | 617 | 127 | 596 | 026 | 428 | .91799 |
| 45 | .88849 | 396 | .89909 | 380 | .90812 | 211 | 584 |
| 50 | 626 | 174 | 684 | 160 | 596 | .90997 | 370 |
| 55 | 393 | .88945 | 458 | .89933 | 367 | 768 | 144 |
| 60 | 169 | 720 | 232 | 707 | 144 | 549 | .90927 |
| 65 | .87938 | 490 | 006 | 479 | .89920 | 328 | 707 |
| 70 | 705 | 254 | .88773 | 252 | 695 | 104 | 484 |
| 75 | 466 | 018 | 538 | 018 | 464 | .89872 | 252 |
| 80 | 228 | .87776 | 301 | .88781 | 225 | 639 | 021 |
| 85 | .86984 | 541 | 067 | 551 | .88998 | 409 | .89793 |
| 90 | 743 | 302 | .87827 | 312 | 758 | 173 | 558 |
| 95 | 499 | 060 | 586 | 069 | 521 | .88937 | 322 |
| 100 | 254 | .86813 | 340 | .87824 | 271 | 691 | 082 |

## TABLE IV—Continued.

*Specific gravities at different temperatures.*

| Temperature. | 100 grains of spirit combined with successive weights of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 + 70 | 100 + 75 | 100 + 80 | 100 + 85 | 100 + 90 | 100 + 95 | 100 + 100 |
| 30° | .92563 | .92889 | .93191 | .93474 | .93741 | .93991 | .94222 |
| 35 | 355 | 680 | .92986 | 274 | 541 | 790 | .94025 |
| 40 | 151 | 476 | 783 | 072 | 341 | 592 | .93827 |
| 45 | .91937 | 264 | 570 | .92859 | 131 | 382 | 621 |
| 50 | 723 | 050 | 358 | 647 | .92919 | 177 | 419 |
| 55 | 502 | .91837 | 145 | 436 | 707 | .92963 | 208 |
| 60 | 287 | 622 | .91933 | 225 | 499 | 758 | 002 |
| 65 | 066 | 400 | 715 | 010 | 283 | 546 | .92794 |
| 70 | .90847 | 181 | 493 | .91793 | 069 | 333 | 580 |
| 75 | 617 | .90952 | 270 | 569 | .91849 | 111 | 364 |
| 80 | 385 | 723 | 042 | 340 | 622 | .91891 | 142 |
| 85 | 157 | 496 | .90818 | 119 | 403 | 670 | .91923 |
| 90 | .89925 | 270 | 590 | .90891 | 177 | 446 | 705 |
| 95 | 688 | 037 | 358 | 662 | .90949 | 221 | 481 |
| 100 | 453 | .89798 | 123 | 428 | 718 | .90992 | 252 |

## TABLE IV—Continued.

*Specific gravities at different temperatures.*

| Temperature. | Successive weights of spirit combined with 100 grains of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 95 + 100 | 90 + 100 | 85 + 100 | 80 + 100 | 75 + 100 | 70 + 100 | 65 + 100 |
| 30° | .94447 | .94675 | .94920 | .95173 | .95429 | .95681 | .95944 |
| 35 | 219 | 484 | 734 | .94988 | 246 | 502 | 772 |
| 40 | 058 | 295 | 547 | 802 | 060 | 328 | 602 |
| 45 | .93860 | 096 | 348 | 605 | .94871 | 143 | 423 |
| 50 | 658 | .93897 | 149 | 414 | 683 | .94958 | 243 |
| 55 | 452 | 696 | .93948 | 213 | 486 | 767 | 057 |
| 60 | 247 | 493 | 749 | 018 | 296 | 579 | .94876 |
| 65 | 040 | 285 | 546 | .93842 | 099 | 388 | 689 |
| 70 | .92828 | 076 | 337 | 616 | .93898 | 193 | 500 |
| 75 | 613 | .92865 | 132 | 413 | 695 | .93989 | 301 |
| 80 | 393 | 646 | .92917 | 201 | 488 | 785 | 102 |
| 85 | 179 | 432 | 700 | .92989 | 282 | 582 | .93902 |
| 90 | .91962 | 220 | 491 | 779 | 075 | 381 | 703 |
| 95 | 740 | .91998 | 272 | 562 | .92858 | 170 | 497 |
| 100 | 513 | 769 | 047 | 346 | 646 | .92957 | 293 |

## TABLE IV—Continued.

*Specific gravities at different temperatures.*

| Temperature. | Successive weights of spirit combined with 100 grains of water. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 60 + 100 | 55 + 100 | 50 + 100 | 45 + 100 | 40 + 100 | 35 + 100 | 30 + 100 |
| 30 | .96209 | .96470 | .96719 | .96967 | .97200 | .97418 | .97635 |
| 35 | 048 | 315 | 579 | 840 | 086 | 319 | 556 |
| 40 | .95879 | 159 | 434 | 706 | .96967 | 220 | 472 |
| 45 | 705 | .95993 | 280 | 563 | 840 | 110 | 384 |
| 50 | 534 | 831 | 126 | 420 | 708 | .96995 | 294 |
| 55 | 357 | 662 | .95966 | 272 | 575 | 877 | 181 |
| 60 | 181 | 493 | 804 | 122 | 437 | 752 | 074 |
| 65 | 000 | 318 | 635 | .95962 | 288 | 620 | .96959 |
| 70 | .94813 | 139 | 469 | 802 | 143 | 484 | 836 |
| 75 | 623 | .94957. | 292 | 638 | .95987 | 344 | 708 |
| 80 | 431 | 768 | 111 | 467 | 826 | 192 | 568 |
| 85 | 236 | 579 | .94932 | 297 | 667 | 046 | 427 |
| 90 | 042 | 389 | 748 | 123 | 502 | .95889 | 293 |
| 95 | .93839 | 196 | 563 | .94944 | 328 | 727 | 139 |
| 100 | 638 | .93999 | 368 | 759 | 152 | 556 | .95983 |

## TABLE IV—Continued.

*Specific gravities at different temperatures.*

| Temperature. | Successive weights of spirit combined with 100 grains of water. | | | | | Water. |
|---|---|---|---|---|---|---|
| | 25 + 100 | 20 + 100 | 15 + 100 | 10 + 100 | 5 + 100 | |
| 30 | .97860 | .98108 | .98412 | .98804 | .99334 | ..... |
| 35 | 801 | 076 | 397 | 804 | 344 | 1.00090 |
| 40 | 737 | 033 | 373 | 795 | 345 | 1.00094 |
| 45 | 666 | .97980 | 338 | 774 | 338 | 1.00086 |
| 50 | 589 | 920 | 293 | 745 | 316 | 1.00068 |
| 55 | 500 | 847 | 239 | 702 | 284 | 1.00038 |
| 60 | 409 | 771 | 176 | 654 | 244 | 1.00000 |
| 65 | 309 | 688 | 106 | 594 | 194 | .99950 |
| 70 | 203 | 596 | 028 | 527 | 134 | .99894 |
| 75 | 086 | 495 | .97943 | 454 | 066 | .99830 |
| 80 | .96963 | 385 | 845 | 367 | .98991 | .99759 |
| 85 | 843 | 271 | 744 | 281 | 912 | .99681 |
| 90 | 711 | 153 | 637 | 185 | 824 | .99598 |
| 95 | 568 | 025 | 523 | 082 | 729 | .99502 |
| 100 | 424 | .96895 | 401 | .97969 | 625 | .99402 |

27. Although the first series of results of Messrs. Gilpin and Blagden escaped criticism until the second series had been performed, yet "when all the experiments had been completed and the tables given were just brought into order, an ingenious member of the Royal Society (Mr. Ramsden) scarcely less celebrated for his theoretical knowledge than his skill as an artist, published a pamphlet containing censures on the first experiments, and proposing other methods, as much superior to those adopted."

In answer to those censures they remark: "This pamphlet makes it necessary to assign the motives of our preference, that the public may judge how far we are justified.

"As to the proportions of the mixtures, which were made by taking an equal quantity of spirit in every instance, and adding to it successively larger quantities of distilled water, as far as to an equal weight, with the intention of going through the watery mixtures on the same plan. This was done for the following reasons: 1. Because it was thought more likely to avoid blunders, if the quantity of only one of the ingredients was changeable, that the operator might not have his attention distracted with computing and weighing out two different quantities for each mixture. 2. Because by this progression the experiments come closer together about the medium degrees of strength, where it was supposed most accuracy would be wanted for practice. 3. As it was thought from the first, that the best method of adjusting the duty would be by the absolute quantity of alcohol in any mixture, rather than the proportion per cent., or the strength above or under proof, it was judged most expedient not to make the mixtures on either of the two last mentioned principles, lest an undue bias should be given to the judgment, merely from the mode of conducting the experiments. No real difficulty can arise in forming tables of any kind out of these numbers, which answer to an harmonic progression of strength. If the operation be tedious to obtain the specific gravity of any single proportion per cent. or otherwise of alcohol and water, the trouble of reducing the whole to a table would not be great, and when once executed, it is done forever."

28. "It is now to be explained why we undertook to determine the effect of heat and cold on the fluids by means of the weighing bottle. When, preparatory to our former experiments, that part of the subject came under our consideration, the method of ascertaining the expansions and contractions, by means of instruments like thermometers, was one of the first that presented itself. On this occasion Mr. Cavendish was so good as to mention some experiments made by his father, Lord Charles Cavendish, with instruments on that construction, for the very purpose of determining the expansion of fluids, and other experiments of the same nature, have appeared in print. The application of this method, however, was thought liable to a most important objection, from the great difficulty there is of being sure that the spirits in the ball are exactly of the temperature indicated by the thermometer placed by the side of it. To enlarge upon this circumstance would be use-

less, as every person accustomed to experiments is aware that all possible precautions, joined to the utmost attention in the observer, are scarcely sufficient to insure this essential correspondence of temperature; which reason alone would have induced us to prefer the method by weight. But there was another argument which still more forcibly determined us in favor of the latter; namely, that the effect of mixture was found in that way, and therefore we were sure it admitted of as great accuracy as was obtained in the other part of the experiments. Greater nicety, if there had been a method which allowed it, would have been superfluous; and to incur the risk of less accuracy would have been absolutely unjustifiable. By using the same method to determine all the changes of specific gravity, those from heat as well as those from mixture, an uniformity is given to the whole series of experiments, and no one part of the results is liable to more suspicion than another.

" Till this time, I believe, the instruments with a ball and tube, for trying expansions, had all been constructed in the manner of real thermometers, to be filled by means of heat; which circumstance, and the trouble attending it, was a further objection to their use; but, in the pamphlet above mentioned, are proposed two instruments of this nature, to be filled without heat—one being provided with two equal tubes, the other with a short tube, closed by a stopper. Though both these instruments, and especially the latter, seemed liable to several causes of error; yet, to remove doubt, and bring the method by weight to a proper test, Mr. Gilpin was desired to make some trials with them. With no small difficulty, Mr. Gilpin got the instruments executed; and an account of the experiments to which he subjected them shall be given in his own words at the end of this report.* From the perusal of that account, it will be perceived that the disagreement of the experiments among themselves is nearly equal to the quantity by which any of them differ from the expansions as obtained by weight. On the whole, however, they give the expansion somewhat less, the cause of which I do not see; possibly it may depend on the fluid in the ball not being quite heated and cooled to the degree shown by the accompanying thermometer; possibly there may be a difference in the expansion of the glass with which the instruments were made, and that of the weighing bottle; for these numbers are in both cases the excess of the expansion of the fluid over glass; or it may turn on some other circumstance which has eluded our attention. Whatever may have occasioned the deficiency, I think the experiments will satisfy any one that most dependence is to be placed on the weights; and, at all events, the difference is not such as to affect the third place of decimals, or, consequently, the table intended for practice."

29. "It is true that the experiments by weight took up much time, and demanded great patience. But I believe that similar experiments, by the methods recommended in the pamphlet, if ex-

* Philos. Trans., vol. 82, p. 439.—1792.

ecuted with the same degree of accuracy, would be found not much less tedious. However this may be, it is a consideration of no consequence, provided the results at length obtained be right. Now, of these there is no direct impeachment, though some doubts are thrown upon them on four accounts—evaporation, condensation of moisture on the weighing bottle, difficulty of shaking the fluid in it, and uncertainty in determining the heat. With regard to evaporation, its effect, we hope, has been ascertained and allowed for in these new experiments. All error from condensation of moisture was obviated by careful wiping. The fluid in the weighing bottle was agitated and mixed together by means of the thermometer immersed in it: besides which, a considerable degree of motion could be given to it, even when the ball was very nearly full, by shaking the bottle in various directions. Mr. Gilpin's known accuracy, and the care he bestowed on these experiments, must gain him credit for having duly watched the thermometer, so as to seize the moment when it gave the just temperature of the mass.

"Our experiments were finished, and the tables now given were drawn out, before the appearance of Mr. Ramsden's pamphlet. Yet, if any of the methods he proposed had been really preferable, the whole series should have been repeated on that new plan, and particularly with regard to the effect of heat, if the instruments for that purpose had been found to answer the character given of them. But, as this was not the case, we have thought it right to adhere to an obvious and direct method, in which, however laborious, there can be no fallacy, and the uniformity of which insures an equal degree of accuracy to every part of the operation."

30. With reference to the best mode of determining the duty which should be paid upon any liquor, Mr. Blagden, in his first report, remarks: "The simplest and most equitable method of levying the duty on spirituous liquors would be to consider rectified spirit as the true and only excisable matter. On this principle all such liquors would pay exactly according to the quantity of rectified spirit they contain; so that when a cask, for instance, of any spirits was presented to the revenue officer, his business would be to determine from the quantity, specific gravity, and temperature of the liquor, how many gallons, or pounds, of rectified spirit enter into its composition, each of which gallons or pounds should be charged a certain sum. The complicated regulations attending the adaptation of the duties to different degrees of strength would thus be avoided; and it is believed that many frauds might be prevented, which artful persons have now an opportunity of practising by altering the strength of their spirit in a variety of ways. From the tables already recommended, it would be easy to deduce this quantity of rectified spirit, either by weight or measure, in any given quantity of a spirituous liquor; or other tables might be constructed which should show it at once by inspection.

31. "If, however, it be thought by government most expedient

not to make any essential change in the present manner of collecting this article of the revenue, I would at least recommend that the specific gravity should be substituted for the relation to proof spirit. Thus, instead of ordering so much duty per gallon to be paid by spirits one to six under proof, it may be enacted that the same sum shall be paid by spirit of .9335 specific gravity; or, not to be too precise, by spirit from .930 to .935, and so on for any other degrees of strength; a certain temperature, suppose 60°, being always understood to be meant when specific gravity is mentioned in an act of Parliament.

"The duties to be laid, according to either of these methods, may readily be adjusted or equalized to those paid at present, as far as the latter can be determined from act of 2 George III., referred to above, or by any of the instruments now in use."

32. "The reasons for not adopting proof spirit, the standard to which most of the regulations of the excise have hitherto been referred, are: First, the strength of spirit to be called proof is a mere arbitrary point, and by no means so exactly determined as could be wished. And, secondly, that it seemed most convenient to take for the standard the highest strength of spirit usually found in commerce, and beyond which it cannot be rectified without a process of some expense; so that all the other degrees of strength might be reckoned one way, without the intervention of a middle point, inducing the necessity of denominating some *above* and others *under*. If, however, government should find it expedient to preserve the reference to proof spirit, from the tables given in this report, others may be constructed in which all the old terms of over and under proof should be retained, and have a precise meaning, as soon as the strength to be called proof shall be finally settled. By the act of 2 George III., it is ordered, that the gallon of brandy or spirits of the strength of one to six, under proof, shall be taken and reckoned at 7 lbs. 13 oz., which is understood by the trade to mean at 55° of heat. Hence, taking the weight of a gallon of water, at the same heat, to be 8 lbs. 5.66, &c., oz., the specific gravity of this diluted spirit will be found, .9335, at 60°; whence, by a computation founded on the tables in this report, the specific gravity of proof spirit will come out, .916. But the rulers of correction belonging to Dicas's and Quin's hydrometers give the specific gravity of proof spirits, about .922, at 55°; equivalent to .920, at 60°. The former, .916, corresponds to a mixture of 100 parts of spirit with 62 by measure, or 75 by weight, of water; and the latter, .920, to a mixture of 100 parts of spirit and 66 by measure, or 80 by weight, of water. The difference is considerable; but the first is undoubtedly most conformable to the existing acts of Parliament. If, therefore, it be thought right to preserve the term proof spirit in our excise laws, it may be understood to mean spirit, whose specific gravity is .916, and which is composed of 100 parts of rectified spirit, at .825, and 62 parts of water by measure, or 75 by weight; the whole at 60 degrees of heat.

"I have chosen this point of the thermometer, 60°, in preference

to 55°, because it is much the most suitable for experiments, being the temperature at which a room feels pleasant, and in which any operation, however slow and tedious, can be executed without the uneasy sensation of cold: for this reason it has been adopted by many English philosophers."

33. In the second or supplementary report, Mr. Blagden adds: "I am still of the opinion, that the best way of laying the duty would be directly on the quantity of alcohol contained in any composition. As the same principle may be applied in estimating the strength, and taking stock, I will mention in what manner the computation can be most readily made. From the numbers in this supplementary report, a table must be constructed, on the top of which shall stand every degree of heat, from 40, or 30, to 80; and at the side every specific gravity, from .825 to 1,000, if it be thought necessary, or as much as will answer the purpose. The places of this table are to be filled up by computing from the original tables, the quantity, by measure, of alcohol and water corresponding to each specific gravity and degree of heat, and then dividing the quantity of alcohol by the whole quantity of the mixture; thus a decimal multiplier will be obtained, which must be put in the compartment of the table formed by the intersection of the columns of that particular heat and specific gravity. When the table is completed in this manner, we have only to multiply the contents of any cask, as found on guaging it, by the decimal number given in the table for the heat and specific gravity of the liquor, and the product will be the quantity of pure alcohol it contains. Hence it must be evident, that no objection can lie to this method on account of difficulty."

34. Finally, in the third and last report, (a second interval of two years having elapsed,) Messrs. Gilpin & Blagden give a table of such "decimal multipliers," computed from the data contained in the table of the supplementary report, and "by means of which, the quantity, by measure, of standard pure spirit, of .825 specific gravity, at 60° of heat, may at once be ascertained, the temperature and specific gravity of the liquor being given; pursuant to the idea suggested in the first report, that 'the simplest and most equitable method of levying the duty on spirituous liquors would be, to consider rectified spirit (alcohol) as the true and only excisable matter.'"

From the table to which reference is made, the following less complete one has been compiled:

# TABLE V.

*Decimal multipliers of the gauged contents.*

| Spirit and water, by weight. | 30° Fahrenheit. | | 35° Fahrenheit. | | 40° Fahrenheit. | | 45° Fahrenheit. | | 50° Fahrenheit. | | 55° Fahrenheit. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. |
| Sp. W. 100 + 0 | .8389 | 1.0169 | .8367 | 1.0142 | .8344 | 1.0114 | .8321 | 1.0087 | .8298 | 1.0058 | .8274 | 1.0029 |
| 5 | .8499 | 0.9812 | .8477 | 0.9786 | .8454 | 0.9759 | .8431 | .9733 | .8408 | 0.9706 | .8383 | 0.9678 |
| 10 | .8596 | .9472 | .8572 | .9447 | .8551 | .9422 | .8528 | .9397 | .8504 | .9371 | .8480 | .9345 |
| 15 | .8682 | .9151 | .8659 | .9126 | .8636 | .9103 | .8613 | .9078 | .8590 | .9054 | .8566 | .9029 |
| 20 | .8753 | .8847 | .8736 | .8824 | .8713 | .8801 | .8690 | .8778 | .8668 | .8755 | .8644 | .8731 |
| 25 | .8828 | .8560 | .8806 | .8539 | .8784 | .8518 | .8761 | .8496 | .8738 | .8474 | .8715 | .8451 |
| 30 | .8892 | .8291 | .8870 | .8270 | .8848 | .8250 | .8825 | .8229 | .8803 | .8208 | .8780 | .8186 |
| 35 | .8951 | .8037 | .8929 | .8017 | .8907 | .7998 | .8885 | .7977 | .8863 | .7957 | .8839 | .7936 |
| 40 | .9005 | .7797 | .8984 | .7778 | .8962 | .7759 | .8940 | .7740 | .8917 | .7721 | .8894 | .7701 |
| 45 | .9056 | .7570 | .9034 | .7552 | .9013 | .7534 | .8991 | .7516 | .8968 | .7497 | .8946 | .7478 |
| 50 | .9102 | .7355 | .9081 | .7338 | .9060 | .7321 | .9038 | .7303 | .9016 | .7286 | .8993 | .7267 |
| 55 | .9145 | .7151 | .9124 | .7135 | .9103 | .7118 | .9081 | .7102 | .9060 | .7085 | .9037 | .7067 |
| 60 | .9185 | .6953 | .9164 | .6942 | .9143 | .6926 | .9121 | .6910 | .9099 | .6894 | .9077 | .6876 |
| 65 | .9222 | .6774 | .9201 | .6760 | .9180 | .6744 | .9158 | .6728 | .9137 | .6712 | .9114 | .6696 |
| 70 | .9256 | .6600 | .9235 | .6585 | .9215 | .6570 | .9194 | .6555 | .9172 | .6540 | .9150 | .6524 |
| 75 | .9289 | .6434 | .9268 | .6419 | .9248 | .6405 | .9226 | .6391 | .9205 | .6376 | .9184 | .6361 |
| 80 | .9319 | .6275 | .9299 | .6262 | .9278 | .6248 | .9257 | .6234 | .9236 | .6219 | .9214 | .6205 |
| 85 | .9317 | .6124 | .9327 | .6111 | .9307 | .6098 | .9286 | .6084 | .9265 | .6070 | .9244 | .6056 |
| 90 | .9374 | .5980 | .9354 | .5967 | .9334 | .5955 | .9313 | .5941 | .9292 | .5928 | .9271 | .5914 |
| 95 | .9399 | .5843 | .9379 | .5830 | .9359 | .5818 | .9338 | .5805 | .9318 | .5792 | .9296 | .5779 |
| 100 | .9422 | .5710 | .9402 | .5693 | .9383 | .5686 | .9362 | .5674 | .9342 | .5662 | .9321 | .5649 |

## TABLE V.—Continued.

*Decimal muitipliers of the gauged contents.*

| Spirit and water, by weight. | 60° Fahrenheit. | | 65° Fahrenheit. | | 70° Fahrenheit. | | 75° Fahrenheit. | | 80° Fahrenheit. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. |
| Sp. W. | | | | | | | | | | |
| 100 + 0 | .8250 | 1.0000 | .8226 | .9971 | .8202 | .9942 | .8178 | .9913 | .8153 | .9882 |
| 5 | .8360 | .9651 | .8336 | .9623 | .8312 | .9596 | .8288 | .9567 | .8263 | .9539 |
| 10 | .8457 | .9319 | .8433 | .9293 | .8409 | .9266 | .8385 | .9239 | .8360 | .9212 |
| 15 | .8543 | .9005 | .8519 | .8980 | .8495 | .8954 | .8471 | .8930 | .8447 | .8903 |
| 20 | .8621 | .8708 | .8598 | .8684 | .8574 | .8660 | .8550 | .8636 | .8525 | .8611 |
| 25 | .8692 | .8428 | .8669 | .8406 | .8645 | .8383 | .8621 | .8360 | .8597 | .8336 |
| 30 | .8757 | .8165 | .8734 | .8143 | .8710 | .8122 | .8686 | .8099 | .8662 | .8077 |
| 35 | .8817 | .7916 | .8794 | .7896 | .8770 | .7875 | .8747 | .7853 | .8723 | .7832 |
| 40 | .8872 | .7681 | .8849 | .7662 | .8825 | .7641 | .8802 | .7621 | .8778 | .7600 |
| 45 | .8923 | .7459 | .8901 | .7440 | .8877 | .7421 | .8854 | .7401 | .8830 | .7381 |
| 50 | .8970 | .7249 | .8948 | .7231 | .8925 | .7212 | .8902 | .7193 | .8878 | .7174 |
| 55 | .9014 | .7049 | .8992 | .7032 | .8969 | .7014 | .8946 | .6996 | .8922 | .6977 |
| 60 | .9055 | .6860 | .9033 | .6843 | .9010 | .6826 | .8987 | .6808 | .8964 | .6791 |
| 65 | .9093 | .6680 | .9071 | .6663 | .9048 | .6647 | .9025 | .6630 | .9002 | .6613 |
| 70 | .9129 | .6509 | .9107 | .6493 | .9085 | .6477 | .9062 | .6461 | .9038 | .6445 |
| 75 | .9162 | .6346 | .9140 | .6331 | .9118 | .6316 | .9095 | .6300 | .9072 | .6284 |
| 80 | .9193 | .6191 | .9171 | .6176 | .9149 | .6161 | .9127 | .6146 | .9105 | .6131 |
| 85 | .9222 | .6043 | .9201 | .6028 | .9179 | .6014 | .9157 | .6000 | .9134 | .5985 |
| 90 | .9250 | .5901 | .9228 | .5987 | .9207 | .5974 | .9185 | .5860 | .9162 | .5845 |
| 95 | .9276 | .5766 | .9255 | .5753 | .9233 | .5739 | .9211 | .5726 | .9189 | .5712 |
| 100 | .9300 | .5636 | .9279 | .5624 | .9258 | .5611 | .9236 | .5598 | .9214 | .5584 |

## TABLE V.—Continued.

*Decimal multipliers of gauged contents.*

| Water and spirit, by weight. | 30° Fahrenheit. | | 35° Fahrenheit. | | 40° Fahrenheit. | | 45° Fahrenheit. | | 50° Fahrenheit. | | 55° Fahrenheit. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W. Sp. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. |
| 100 + 95 | .9445 | .5577 | .9425 | .5566 | .9406 | .5554 | .9386 | .5543 | .9366 | .5531 | .9345 | .5518 |
| 90 | 67 | .5430 | 48 | .5425 | 29 | .5414 | .9410 | .5403 | 90 | .5391 | 70 | .5380 |
| 85 | 92 | .5286 | 73 | .5276 | 55 | .5265 | 35 | .5254 | .9415 | .5243 | 95 | .5232 |
| 80 | .9517 | .5127 | 99 | .5117 | 80 | .5107 | 60 | .5097 | 41 | .5086 | .9421 | .5075 |
| 75 | 43 | .4957 | .9525 | .4948 | .9506 | .4938 | 87 | .4928 | 68 | .4919 | 49 | .4908 |
| 70 | 68 | .4775 | 50 | .4767 | 33 | .4758 | .9514 | .4749 | 96 | .4739 | 77 | .4730 |
| 65 | 94 | .4581 | 77 | .4573 | 60 | .4565 | 42 | .4557 | .9524 | .4548 | .9506 | .4539 |
| 60 | .9621 | .4373 | .9605 | .4366 | 88 | .4358 | 70 | .4350 | 53 | .4342 | 36 | .4334 |
| 55 | 47 | .4149 | 31 | .4143 | .9616 | .4136 | 99 | .4129 | 83 | .4122 | 66 | .4114 |
| 50 | 72 | .3903 | 57 | .3902 | 43 | .3896 | .9628 | .3890 | .9613 | .3884 | 97 | .3877 |
| 45 | 97 | .3648 | 84 | .3643 | 71 | .3638 | 56 | .3633 | 42 | .3627 | .9627 | .3622 |
| 40 | .9720 | .3360 | .9709 | .3362 | 97 | .3358 | 84 | .3354 | 71 | .3349 | 57 | .3345 |
| 35 | 42 | .3001 | 32 | .3058 | .9722 | .3055 | .9711 | .3052 | 99 | .3048 | 88 | .3044 |
| 30 | 03 | .2731 | 56 | .2729 | 47 | .2726 | 38 | .2724 | .9728 | .2721 | .9718 | .2718 |
| 25 | 86 | .2372 | 80 | .2371 | 74 | .2369 | 67 | .2368 | 59 | .2366 | 50 | .2364 |
| 20 | .9811 | .1982 | .9808 | .1981 | .9803 | .1980 | 98 | .1979 | 92 | .1978 | 85 | .1977 |
| 15 | 41 | .1556 | 40 | .1556 | 37 | .1555 | .9834 | .1555 | .9829 | .1554 | .9824 | .1553 |
| 10 | 80 | .1089 | 80 | .1089 | 79 | .1089 | 77 | .1088 | 74 | .1088 | 70 | .1088 |
| 5 | .9933 | .0573 | 34 | .0573 | 34 | .0573 | .9933 | .0573 | .9931 | .0573 | .9928 | .0573 |

## TABLE V—Continued.

*Decimal multipliers of gauged contents.*

| Water and spirit, by weight. | 60° Fahrenheit. | | 65° Fahrenheit. | | 70° Fahrenheit. | | 75° Fahrenheit. | | 80° Fahrenheit. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. | Sp. grav. | Decl. mult. |
| W. Sp. | | | | | | | | | | |
| 100 + 95 | .9325 | .5506 | .9304 | .5494 | .9283 | .5482 | .9261 | .5469 | .9239 | .5456 |
| 90 | 49 | .5368 | 28 | .5356 | .9308 | .5344 | 86 | .5332 | 65 | .5319 |
| 85 | 75 | .5221 | 55 | .5210 | 34 | .5198 | .9313 | .5187 | 92 | .5175 |
| 80 | .9402 | .5065 | 82 | .5054 | 62 | .5043 | 41 | .5032 | .9320 | .5021 |
| 75 | .9430 | .4898 | .9410 | .4888 | 90 | .4878 | 69 | .4867 | 49 | .4856 |
| 70 | 58 | .4720 | 39 | .4711 | .9419 | .4701 | 99 | .4691 | 78 | .4681 |
| 65 | 88 | .4530 | 69 | .4521 | 50 | .4512 | .9430 | .4503 | .9410 | .4493 |
| 60 | .9518 | .4326 | .9500 | .4318 | 81 | .4310 | 62 | .4301 | 43 | .4292 |
| 55 | 49 | .4107 | 32 | .4100 | .9514 | .4092 | 96 | .4084 | 76 | .4076 |
| 50 | 80 | .3871 | 63 | .3864 | 47 | .3857 | .9529 | .3850 | .9511 | .3843 |
| 45 | .9612 | .3616 | 96 | .3610 | 80 | .3604 | 64 | .3598 | 47 | .3591 |
| 40 | 44 | .3340 | .9629 | .3335 | .9614 | .3330 | 99 | .3324 | 83 | .3319 |
| 35 | 75 | .3040 | 62 | .3036 | 48 | .3032 | .9634 | .3028 | .9619 | .3023 |
| 30 | .9707 | .2715 | 96 | .2712 | 84 | .2709 | 71 | .2705 | 57 | .2701 |
| 25 | 41 | .2361 | .9731 | .2359 | .9720 | .2356 | .9709 | .2354 | 96 | .2351 |
| 20 | 77 | .1975 | 69 | .1973 | 60 | .1971 | 49 | .1970 | .9738 | .1967 |
| 15 | .9818 | .1552 | .9811 | .1551 | .9803 | .1550 | 94 | .1549 | 84 | .1547 |
| 10 | 65 | .1087 | 59 | .1086 | 53 | .1086 | .9845 | .1085 | .9837 | .1084 |
| 5 | .9924 | .0573 | .9919 | .0572 | .9913 | .0572 | .9907 | .0572 | 99 | .0571 |

35. Of instruments to be used by the revenue officers, Messrs. Gilpin and Blagden express the opinion that "the readiest way of ascertaining specific gravities, and undoubtedly the most convenient for public business, is by hydrometers; and those of the simplest construction are best upon the whole, especially if more accurate means are kept at hand to be resorted to in case of disputes. That which can be managed with the greatest facility and quickness, which affords the least opportunity of making blunders, which is least liable to be out of order, and shows most immediately if it be so, will unquestionably prove the most satisfactory in practice."

To glass hydrometers they give the preference "as the most certain," and reject those of copper and other metals "on account of the errors which small and almost imperceptible bruises in them might occasion."

As disputes will sometimes arise, they recommend that "some of the principal excise officers should be provided with a good pair of scales and a weighing bottle properly marked, the quantity of whose contents of distilled water at 60° had been previously determined. By filling this bottle up to the mark with the spirit in question, and dividing its increase of weight by the given weight of water required to fill it, the specific gravity of the spirit would be better ascertained, even under the management of a common operator, than by the most dextrous use of the hydrometer."

*Subsequent inquiries of the British government.*

36. In my former report on the subject of hydrometers, I have remarked* "it is a fact, strange and unaccountable as it may appear, that though Messrs. Gilpin and Blagden performed their task in a manner which could not have been surpassed, and obtained nearly all the information requisite to furnish a perfect instrument and system of inspection for spirits, the British government neglected to apply the knowledge obtained to its legitimate object; and twenty years afterwards, the complicated, imperfect and uncertain hydrometer of Sikes was established by law as that to be used in the revenue of the United Kingdom, though its basis and method of construction are, to a great extent, arbitrary, and seem to have been kept secret by its inventor for purposes of personal emolument."

That I am correct in attributing to the British government such neglect and erroneous action is established by its subsequent application to the Royal Society, and the report of the committee to whom the matter was referred. I have been unable to find that report, for which I have searched diligently, both in the published transactions of the Royal Society and in the British Parliamentary documents, and, therefore, I extract from Ure's Dictionary† the only account of its contents to which I have been able to refer.

*Senate document No. 165, 28th Congress, 2d session, page 71.
† Ure's Dictionary of Arts and Manufactures, page 20: London, 1840.

37. "The importance of extreme accuracy in determining the density of alcoholic mixtures in the United Kingdom, on account of the great revenue derived from them to the State, and their consequent high price in commerce, induced the Lords of the Treasury a few years ago to request the Royal Society to examine the construction and mode of applying the instrument now in use for ascertaining and charging the duty on spirits. This instrument, which is known and described in the law as Sykes's hydrometer, possesses in many respects decided advantages over those formerly in use. The committee of the Royal Society state that a definite mixture of alcohol and water is as invariable in its value as absolute alcohol can be, and can be more readily and with equal accuracy identified by that only quality or condition to which recourse can be had in practice, namely, specific gravity. The committee further proposed, that the standard spirit be that which, consisting of alcohol and water alone, shall have a specific gravity of 0 92 at the temperature of 62° Fahrenheit, water being unity at the same temperature; or, in other words, that it shall, at 62°, weigh $\frac{92}{100}$ or $\frac{23}{25}$ of an equal bulk of water at the same temperature.

"This standard is rather weaker than the old proof, which was $\frac{12}{13}$ or 0.923; or in the proportion of nearly 1.1 gallon of the present proof spirit per cent. The proposed standard will contain nearly one-half by weight of absolute alcohol. The hydrometer ought to be so graduated as to give the indication of strength, not upon an arbitrary scale, but in terms of specific gravity at the temperature of 62°."

38. "The committee recommend the construction of an equation table, which shall indicate the same strength of spirit at every temperature. Thus, in standard spirit at 62°, the hydrometer would indicate .920, which, in this table, would give proof spirit. If that same spirit were cooled to 40°, the hydrometer would indicate some higher number; but which, being combined in the table with the temperature as indicated by the thermometer, should still give proof or standard spirit as the result."

39. "It is considered advisable, in this and the other tables, not to express the quality of the spirit by any number over or under proof, but to indicate at once the number of gallons of standard spirit contained in, or equivalent to, 100 gallons of the spirit under examination. Thus, instead of saying 23 over proof, it is proposed to insert 123; and in place of 35.4 under proof, to insert its difference to 100, or 64.6."

40. "It has been considered expedient to recommend a second table to be constructed, so as to show the bulk of spirit of any strength at any temperature, relative to a standard bulk of 100 gallons at 62°. In this table a spirit, which had diminished in volume, at any given temperature, 0.7 per cent., for example, would be expressed by 99.3, and a spirit which had increased at any given temperature 0.7 per cent., by 100.7."

41. "When a sample of spirit, therefore, has been examined by the hydrometer and thermometer, these tables will give first the proportion of standard spirit at the observed temperature, and next the change of bulk of such spirit from what it would be at the standard temperature. Thus, at the temperature of 51°, and with an indication (Sp. gr.) of .8240, 100 gallons of the spirit under examination would be shown by the first table to be equal to 164.8 gallons of standard spirit of that temperature; and by the second table it would appear, that 99.3 gallons of the same spirit would become 100 at 62°, or in reality contain the 164.8 gallons of spirit in that state only in which it is to be taxed."

42. "But as it is considered that neither of these tables can alone be used for charging the duty, (for neither can express the actual quantity of spirit of a specific gravity of 0.92 at 62° in 100 gallons of stronger or weaker spirit at temperatures above or below 62°,) it is considered essential to have a third table, combining the two former, and expressing this relation directly, so that upon mere inspection it shall indicate the proportion of standard spirit in 100 gallons of that under examination in its then present state. In this table the quantities should be set down in the actual number of gallons of standard spirit, at 62°, equivalent to 100 of the spirit under examination; and the column of quantities may be expressed by the term *value*, as it in reality expresses the proportion of the only valuable substance present. As it will be the only table absolutely necessary to be used with the instrument for the purposes of the excise, it may, perhaps, be thought unnecessary to print the former two.

"The following specimen table has been given by the committee:

| Temperature 45°. | | | Temperature 75°. | | |
|---|---|---|---|---|---|
| Indication. | Strength. | Value. | Indication. | Strength. | Value. |
| .9074 | 114.5 | ..... | 8941 | 114.5 | ..... |
| 77 | 114.3 | ..... | 44 | 114.3 | ..... |
| 79 | 114.2 | ..... | 45 | 114.2 | ..... |
| 81 | 114.0 | ..... | 48 | 114.0 | ..... |
| 83 | 113.9 | ..... | 49 | 113.9 | ..... |
| 85 | 113.7 | ..... | 52 | 113.7 | ..... |
| 86 | 113.6 | ..... | 53 | 113.6 | ..... |
| 89 | 113.4 | ..... | 56 | 113.4 | ..... |
| 90 | 113.3 | ..... | 57 | 113.3 | ..... |
| 93 | 113.1 | ..... | 59 | 113.1 | ..... |

"The mixture of alcohol and water, taken as spirit in Mr. Gilpin's tables, is that of which the specific gravity is 0.825 at 60° Fahr., water being unity at the same temperature. The specific gravity of water at 60° degrees being 100.0 at 62° it is 99.981.

Hence, in order to compare the specific gravities given by Mr. Gilpin, with those which would result when the specific gravity of water at 62° is taken at unity, all the former numbers must be divided by 99.981."

43. "Experiments were made, by direction of the committee, to verify Gilpin's tables, which showed that the error introduced in ascertaining the strength of spirits by tables founded on Gilpin's numbers, must be quite insensible in the practice of the revenue. The discrepancies thus detected, on a mixture of a given strength, did not amount in any one instance to unity in the fourth place of decimals. From a careful inspection of such documents, the committee are of opinion, that Gilpin's tables possess a degree of accuracy far surpassing what could be expected, and sufficiently perfect for all practicable or scientific purposes."

44. "The following table is given by Mr. Lubbock, for converting the apparent specific gravity, or *indication*, into true specific gravity:"

TABLE VI.

| Indication | — Temperature. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30° | 32° | 37° | 42° | 47° | 52° | 57° |
| .82 | .00083 | .00078 | .00065 | .00052 | .00039 | .00025 | .00012 |
| .83 | 84 | 79 | 66 | 52 | 39 | 26 | 12 |
| .84 | 85 | 80 | 66 | 53 | 39 | 26 | 13 |
| .85 | 86 | 81 | 67 | 54 | 40 | 26 | 13 |
| .86 | 87 | 82 | 68 | 54 | 40 | 27 | 13 |
| .87 | 88 | 83 | 69 | 55 | 41 | 27 | 13 |
| .88 | 89 | 84 | 70 | 55 | 41 | 27 | 13 |
| .89 | 90 | 85 | 70 | 55 | 42 | 28 | 13 |
| .90 | 91 | 85 | 71 | 56 | 42 | 28 | 14 |
| .91 | 92 | 86 | 72 | 57 | 43 | 28 | 14 |
| .92 | 93 | 87 | 73 | 58 | 43 | 29 | 14 |
| .93 | 94 | 88 | 73 | 59 | 44 | 29 | 14 |
| .94 | 95 | 89 | 74 | 59 | 44 | 29 | 14 |
| .95 | 96 | 90 | 75 | 60 | 45 | 29 | 14 |
| .96 | 97 | 91 | 76 | 60 | 45 | 30 | 14 |
| .97 | 98 | 92 | 77 | 61 | 46 | 30 | 15 |
| .98 | 99 | 93 | 77 | 62 | 46 | 30 | 15 |
| .99 | .00100 | 94 | 78 | 62 | 47 | 31 | 15 |
| .100 | 101 | 95 | 79 | 63 | 47 | 31 | 15 |

TABLE VI.

| Indication. | + Temperature. | | | | |
|---|---|---|---|---|---|
| | 62° | 67° | 72° | 77° | 80° |
| .82 | ..... | .00011 | .00024 | .00035 | .00042 |
| .83 | ..... | 12 | 24 | 36 | 42 |
| .84 | ..... | 12 | 24 | 36 | 43 |
| .85 | ..... | 12 | 25 | 37 | 43 |
| .86 | ..... | 12 | 25 | 37 | 44 |
| .87 | ..... | 12 | 25 | 37 | 44 |
| .88 | ..... | 12 | 26 | 38 | 45 |
| .89 | ..... | 12 | 26 | 38 | 45 |
| .90 | ..... | 13 | 26 | 39 | 46 |
| .91 | ..... | 13 | 26 | 39 | 46 |
| .92 | ..... | 13 | 27 | 40 | 47 |
| .93 | ..... | 13 | 27 | 40 | 47 |
| .94 | ..... | 13 | 27 | 40 | 48 |
| .95 | ..... | 13 | 28 | 41 | 48 |
| .96 | ..... | 13 | 28 | 41 | 49 |
| .97 | ..... | 14 | 28 | 42 | 49 |
| .98 | ..... | 14 | 28 | 42 | 50 |
| .99 | ..... | 14 | 29 | 43 | 50 |
| .100 | ..... | ..... | ..... | ..... | ..... |

*Investigations for the Prussian government, by Mr. Tralles.*

45. From a few experiments of his own, the celebrated German chemist Richter had constructed hydrometers, indicating the *per cent.* of alcohol by weight contained in any liquor.* Of these instruments the latest and most improved was based upon the following data†, the corresponding temperature being 16° R. = 68° Fahr.:

| Per cent. of alcohol by weight. | Specific gravity. |
|---|---|
| 100.00 | 0.7920 |
| 74.71 | 0.8600 |
| 56.60 | 0.9010 |
| 41.00 | 0.9340 |
| 32.14 | 0.9525 |

To obtain the specific gravities and the graduation of his hydrometer, Richter interpolated for intermediate per cents., and was thus enabled to make instruments of considerable accuracy, which were adopted by the government and generally used in Prussia.

46. As spirituous liquors are always bought and sold by *volume*, and not by *weight*, the use of Richter's hydrometer required trouble-

* See Sen. Doc. No. 165, 28th Congress 2d session, p. 77.
† Handwörterbuch der Chemie, Liebig and Wöhler, vol. 1, p. 214, 1842.

some calculations to be made, which caused much loss of time and frequently error, in the collection of the revenue. The Prussian government, therefore, requested the Academy of Sciences of Berlin to have such investigations made, as might be found necessary to establish a convenient, just, and accurate mode of ascertaining the relative duties to be paid by spirituous liquors. The secretary of the academy, Mr. Tralles, a gentleman distinguished for his skill and attainments in chemical and mathematical science, was entrusted with the requisite experiments and inquiries; the results of which furnished the basis of the beautiful method which was carried into operation at that time, A. D. 1811, by the Prussian govornent; and which has since been adopted by France, Sweden, Austria, Belgium, and other countries.

47. After examining Messrs. Gilpin and Blagden's reports of their researches, Mr. Tralles determined to adopt their results as fundamental data; for this he assigns the following reasons, which are translated from his report.*

"The relation between the strength and the specific gravity of a liquor can be determined only by experiment. Several series of investigations relative to this subject have been performed; but none with such skill and care as those made under the direction of the Royal Society of London, at the request of the British government, for the purpose of ascertaining the proper duties to be levied on spirituous liquors. In France, on a similar occasion, all that was done was to publish advice, especially for the construction of hydrometers."

"It is proper to give a more full account of the above mentioned experiments, which serve as data for the table I have computed, in order that careless experiments may not meet with confidence to which they are not entitled; and that unnecessary and unauthorized examinations of matters fixed by law, as well as the confusion they would produce, may be prevented. It is generally thought that such experiments can be easily made and by any body, but this is a great mistake; to furnish precise results, they demand great skill, and can only be made with such apparatus and facilities as private philosophers can rarely afford. To be convinced of this, it is only necessary to examine the experiments performed in England. They were devised and executed by experienced and highly intelligent observers, and yet they had to be repeated three times, as, after each series, some cause of error was detected. It is true, these experiments were attacked by a highly meritorious gentleman; this happened, however, before the last series were commenced, and when these were published, satisfactory reasons were given in justification of the method which had been adopted."

There are slight errors in the English experiments, to which Mr. Tralles briefly alludes, and then adds: "They are more than sufficiently exact. It will be allowed, therefore, not to recommend to

* Gilbert's Annalen, B. 38, st. 8, 1811, p. 353—355.

the government, as a basis, other experiments less complete and authentic."

48. Of the errors just mentioned in Messrs. Gilpin and Blagden's work, chiefly due to atmospheric buoyancy, Mr. Tralles subsequently remarks: "Notwithstanding the great care with which their reports to the Royal Society are drawn up, I do not find mentioned in them, whether in the experiments attention was paid to the temperature and density of the air, and to the weight of the portion of air in the bottle which is removed by pouring in the liquid. As the weighing was carried, not only to tenths, but even to hundredths of a grain, this ought certainly to have been taken into account. The balance was capable of indicating such differences, and the experiments are, therefore, affected with errors, which the nicety of the weighings cannot set aside. The specific gravities are set down in the tables to 0.00001; to 0.0001 nearly they may be right, even if no attention was paid to the air, as its influence would change the results only a little more than one 10,000th part—an uncertainty which is without influence."*

49. Having satisfied himself that the experiments of Messrs. Gilpin and Blagden possess a degree of accuracy much beyond that required for revenue purposes, or which can be attained in less careful work; Mr. Tralles next turned his attention to the determination of a proper standard to which all other liquors might be referred.

We have already seen that this constituted a preliminary and difficult subject of inquiry in the English experiments, (§ 17,) that unsuccessful attempts to procure pure acohol were then made by both distillers and by a skilful chemist; and that Messers. Gilpin and Blagden, therefore, adopted alcohol of the specific gravity 0.825, the highest degree of strength usually met with in commerce, as the standard spirit of their mixtures.

Mr. Tralles endeavored to obtain pure alcohol and was furnished by the distinguished chemist, Assessor Rose, with two specimens prepared by himself at different times with great care, and rendered as free from water as possible. Of these specimens, Tralles found one to be of the specific gravity 0.7984 at 60° Fahrenheit, and the other 0.79876, water being unity at the same temperature.

In 1796, Mr. Lowitz of St. Petersburg published a method of obtaining alcohol free from water, by which he was enabled to make it of the specific gravity 0.791 at 16° R,=68° Fahrenheit. This alcohol, repeatedly rectified in the same manner, did not become lighter when it was distilled by itself; the first and last

* In his admirable treatise on chemistry, vol. vi., p. 472, of the first French edition, Berzelius speaks of this uncertainty in Messrs. G. and B.'s experiments, as follows: "This third series of experiments furnishes an example which will serve to show how difficult it is to foresee every cause of error in such cases. Gilpin corrected every imperfection which was noticed either by himself or others, in his first series of experiments, and yet he forgot to take into account the air displaced by the liquids weighed, and which exerts an influence appreciable, not only in itself, but even in its variation, for different barometric pressures, with a balance as sensible as that he employed. Still this influence is without importance in practical operations, for the specific gravity reduced to a vacuum is scarcely changed 0.0001."

portions were exactly alike; Mr. Lowitz, therefore, considered it pure or absolute.

Also, as no chemist had been able to produce alcohol of less density than that of Lowitz, and "as Dr. Richter had obtained alcohol of about the same specific gravity, so that it could not be considered a hypothetical substance," Tralles deemed it expedient to adopt the specific gravity 0.791 at 68° Fahrenheit as that of pure alcohol, which density he found by reduction to be equivalent to 0.7946 at 60° Fahrenheit, water at this temperature being unity.

50. The details of the above mentioned reduction have not been published, but in a note by Gilbert,* the following extracts from the original memoranda of Tralles are given: "The specific gravity of water being unity at 60° Fahrenheit, as is always here understood, that of Rose's alcohol was:—

| | | | |
|---|---|---|---|
| At 61°.3 Fahrenheit | = 0.797840 | Difference. | |
| 68 " | = 0.794525 | 6°.7 | = 0.003315 |
| 68 .5 " | = 0.794490 | 7 .2 | = 0.003350 |

"From the first result, the decrement for each degree Fahrenheit is 0.0005; from the second 0.000465; the mean being 0.00048. This Professor Tralles takes as the basis of the reduction to 60° Fahrenheit. The two first results, therefore, give the specific gravities 0 79846 and 0.798365, of which 0.79841 is the mean."

"The following experiments were probably made with the other alcohol of Rose:—

| | | | |
|---|---|---|---|
| At 57°.1 Fahrenheit | = 0.80006 | At 60° | = 0.79868 |
| 66 .2 " | = 0.795834 | 60 | = 0.79874 |
| 61 " | = 0.798404 | 60 | = 0.79887 |
| | | Mean..... | = 0.79876 |

"The following result deserves to be added: At 60° an experiment gave 0.79862; and at 99°, with the same alcohol and method, 0.78069—a difference of 0.0180 for 39°, which is equal to 0.00047 for each degree; exactly the same which the experiments above gave between 61°.3 and 68°.5. To judge from this, it would appear that absolute alcohol expands uniformly between 60° and 99° Fahrenheit—and Professor Tralles informs me that he has found by his experiments that absolute alcohol expands as uniformly between — 15° and + 15° Fahrenheit, as either mercury or air."

51. The law of uniform expansion thus stated by Tralles, is in conflict with subsequent researches of Mr. Gay Lussac,† (§ 86,) though approximately confirmed by the results of Gilpin. (See table IV.) Also, the mean coefficient 0 00048, does not seem to have been used by him in the reduction 0.7946 at 60°, from 0.791 at 68°.

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* See page 361, Ann. der Phys. B. 38, 1811.
† Ann. de Chem. et de Phys. t. 2. p. 134.

On this subject Gilbert says: * "The specific gravity 0.791 would become greater by 0.00384, or 8 times 0.00048; or equal to 0.79484, *water being unity at* 60°. Mr. Tralles seems to have purposely (*mit Fleiss*) assumed a smaller ratio of expansion, or 0.00045 only."

The words in italics have been so marked by myself, because they indicate an error into which Mr. Gilbert has fallen; water is not unity at 60°, but at 68° Fahrenheit,† for Lowitz's specific gravity 0.791; and, if we apply the requisite correction to 0.79484 obtained by Gilbert, we get 0.7942, and not 0.7946, as given by Tralles. Nor by using the ratio 0.0005, the maximum given by any of the above experiments of Tralles, do we find a more satisfactory result; for this gives only 0.7943. Hence, it is evident that Tralles must have used, in the calculations by which he deduced 0.7946 at 60° from 0.791 at 68°, a coefficient of expansion greater than he obtained from his own experiments with Rose's alcohol.

In another part of his report, Tralles states that by several experiments with the alcohol of Mr. Rose, made for the purpose of ascertaining the variations of density produced by adding very small quantities of water, data were obtained for calculating the amount of water to be abstracted, in order to reduce the specific gravity to that of the standard alcohol of Lowitz; and the result was, that alcohol of 0.7986 still contains 0.0129 of its weight of water.

From this result, and the law of gradual increase of dilatation for ascending per cents., we may assume a hypothetical coefficient greater than 0.0005, the maximum given by Rose's alcohol; but to obtain 0.7946, the standard of Tralles, we must employ a coefficient equal to 0.00053; the probable error of which is much too great.

I have discussed this subject fully, because the specific gravity 0.7946, adopted by Tralles, is often referred to as a well determined result; and it is, therefore, fit that whatever uncertainty existed in his work, with reference to this matter, should be clearly pointed out.

52. Having resolved to adopt the work done in England, by Mr. Gilpin, for the same purpose, it became necessary that Mr. Tralles should "determine how much water is contained in alcohol of the specific gravity 0.825, under the hypothesis that only that is pure alcohol of which the density is 0.7946 under like circumstances, or at 60° Fahrenheit, water being unity for the same temperature."

"By a series of experiments, it was ascertained that spirit of 0.825 contains 0.0963 of its weight of water, the rest being alcohol of 0.7986; and as the latter had been found still to contain 0.0129 of its weight of water, it follows, that spirit of the density 0.825

* See note to page 367 of Tralles' report.
† See Handwörterb. der Chem. Liebig & Poggendorff, vol. 1, p. 214.

contains 89.2 per cent. by weight, or 92.6 per cent. by volume of alcohol of the density 0.7946, the least ever found, and which may, therefore, be assumed as absolute or standard alcohol. Upon this result,* and the data in the Philosophical Transactions of the Royal Society, are all the following tables founded."

53. Before giving the tables, referred to in the last article, we may mention the experiments which were made to settle an important question:

"Some are disposed to maintain," says Tralles, "that alcohol deprived of water to so high a degree is not a genuine alcohol, but an altered compound. The chemists, however, who say so, have no proper evidence for the assertion. Yet I deemed it expedient to examine whether there are any physical grounds for such an opinion; or, more precisely, whether, if we add to absolute alcohol as much water as will restore it to the density of the liquor from which it was made, and subsequently compare the densities of mixtures made from it with those of similar mixtures made from the original spirit, the results will be identical. Experiments to decide this question were made by me, and I found that mixtures of absolute alcohol and water, obey the *same laws* as those of rectified spirit or common alcohol. This is the result of experiments made with extreme care; the weighings being, in every instance, carried to the fiftieth of a grain, and the air displaced, as well as the dilatation of the liquid and of the vessel being taken into account. It would render this report too scientific to give the details of these experiments and calculations; which were only the means used to attain the desired end."

*On the second part of Tralles's report.*

54. This section will contain the tables computed by Tralles from the data of Messrs. Gilpin and Blagden. The specific gravities are all reduced to the scale of water 10,000 at its maximum density; so that at 60° F. we have for absolute alcohol, the specific gravity 7939, and 9991. for that of pure water.

55. The first of Tralles's tables, hereto annexed, and marked table VII., gives the specific gravities at 60° Fahr., for mixtures of pure alcohol and water; of which, each 100 gallons, or cubic inches, contain the number of gallons, or cubic inches, of alcohol indicated in the first column, if measured at the same temperature.

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* Mr. Tralles did not publish the experiments from which he deduced this conclusion; and Gilbert says (page 367) the data were not among the papers confided to him. "Das Detail dieser beiden Versuchsreihen findet sich zufällig nicht in dem mir von dem Hrn. Verfasser anvertrauten Theile der Protokolle über seine Versuche."

TABLE VII.

| Per cent. of alcohol by volume. | Specific gravity at 60° Fahrenheit. | Differences of specific gravity. | Per cent. on alcohol by volume. | Specific gravity at 60° Fahrenheit. | Differences of specific gravity. |
|---|---|---|---|---|---|
| 0 | 9991 | | 51 | 9315 | 20 |
| 1 | 9976 | 15 | 52 | 9295 | 20 |
| 2 | 9961 | 15 | 53 | 9275 | 20 |
| 3 | 9947 | 14 | 54 | 9254 | 21 |
| 4 | 9933 | 14 | 55 | 9234 | 20 |
| 5 | 9919 | 14 | 56 | 9213 | 21 |
| 6 | 9906 | 13 | 57 | 9192 | 21 |
| 7 | 9893 | 13 | 58 | 9170 | 22 |
| 8 | 9881 | 12 | 59 | 9148 | 22 |
| 9 | 9869 | 12 | 60 | 9126 | 22 |
| 10 | 9857 | 12 | 61 | 9104 | 22 |
| 11 | 9845 | 12 | 62 | 9082 | 22 |
| 12 | 9834 | 11 | 63 | 9059 | 23 |
| 13 | 9823 | 11 | 64 | 9036 | 23 |
| 14 | 9812 | 11 | 65 | 9013 | 23 |
| 15 | 9802 | 10 | 66 | 8989 | 24 |
| 16 | 9791 | 11 | 67 | 8965 | 24 |
| 17 | 9781 | 10 | 68 | 8941 | 24 |
| 18 | 9771 | 10 | 69 | 8917 | 24 |
| 19 | 9761 | 10 | 70 | 8892 | 25 |
| 20 | 9751 | 10 | 71 | 8867 | 25 |
| 21 | 9741 | 10 | 72 | 8842 | 25 |
| 22 | 9731 | 10 | 73 | 8817 | 25 |
| 23 | 9720 | 11 | 74 | 8791 | 26 |
| 24 | 9710 | 10 | 75 | 8765 | 26 |
| 25 | 9700 | 10 | 76 | 8739 | 26 |
| 26 | 9689 | 11 | 77 | 8712 | 27 |
| 27 | 9679 | 10 | 78 | 8685 | 27 |
| 28 | 9668 | 11 | 79 | 8658 | 27 |
| 29 | 9657 | 11 | 80 | 8631 | 27 |
| 30 | 9646 | 11 | 81 | 8603 | 28 |
| 31 | 9634 | 12 | 82 | 8575 | 28 |
| 32 | 9622 | 12 | 83 | 8547 | 28 |
| 33 | 9609 | 13 | 84 | 8518 | 29 |
| 34 | 9596 | 13 | 85 | 8488 | 30 |
| 35 | 9583 | 13 | 86 | 8458 | 30 |
| 36 | 9570 | 13 | 87 | 8428 | 30 |
| 37 | 9556 | 14 | 88 | 8397 | 31 |
| 38 | 9541 | 15 | 89 | 8365 | 32 |
| 39 | 9526 | 15 | 90 | 8332 | 33 |
| 40 | 9510 | 16 | 91 | 8299 | 33 |
| 41 | 9494 | 16 | 92 | 8265 | 34 |
| 42 | 9478 | 16 | 93 | 8230 | 35 |
| 43 | 9461 | 17 | 94 | 8194 | 36 |
| 44 | 9444 | 17 | 95 | 8157 | 37 |
| 45 | 9427 | 17 | 96 | 8118 | 39 |
| 46 | 9409 | 18 | 97 | 8077 | 41 |
| 47 | 9391 | 18 | 98 | 8034 | 43 |
| 48 | 9373 | 18 | 99 | 7988 | 46 |
| 49 | 9354 | 19 | 100 | 7939 | 49 |
| 50 | 9335 | 19 | | | |

56. In this table the third column gives the differences of the numbers in the second, and is designed to be used for interpolating, by proportion, values intermediate to those given in the first and second columns.

57. It may be well, perhaps, to remark, that if 100 gallons of spirit contain, for instance, 40 gallons of alcohol, at 60° F., as indicated in the first column of the preceding table, it would be erroneous to conclude that the same liquor also contains 60 gallons only of water. Such could only be the case, if no contraction or diminution of volume took place, when alcohol and water are mixed.

58. When the specific gravity of a spirituous liquor is taken, its temperature will very seldom be either exactly or very nearly 60° F.; hence it is necessary in using table VII. to apply corrections to the observed specific gravities, in order to reduce them to the values which would have been found experimentally at 60° F. For this purpose, to avoid calculations, Tralles has computed the following table:

TABLE VIII.

*Variations of the specific gravities of spirits for different temperatures.*

| Per cent. by vol. of pure alcohol, at 60° Fahr. | Specific gravity at 60° Fahrenheit. | *Increase* of the specific gravities corresponding to the various per cents., at 60°, for the following degrees of Fahrenheit's thermometer. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 55° | 50° | 45° | 40° | 35° | 30° |
| 0 | 9991 | 4 | 7 | 9 | 9 | 9 | 7 |
| 5 | 9919 | 4 | 7 | 9 | 10 | 10 | 9 |
| 10 | 9857 | 5 | 9 | 12 | 14 | 15 | 15 |
| 15 | 9802 | 6 | 12 | 17 | 21 | 23 | 25 |
| 20 | 9751 | 8 | 16 | 23 | 29 | 35 | 39 |
| 25 | 9700 | 10 | 21 | 31 | 39 | 48 | 56 |
| 30 | 9646 | 13 | 26 | 39 | 51 | 62 | 73 |
| 35 | 9583 | 16 | 31 | 46 | 61 | 75 | 89 |
| 40 | 9510 | 18 | 35 | 52 | 70 | 87 | 103 |
| 45 | 9427 | 19 | 39 | 57 | 76 | 94 | 112 |
| 50 | 9335 | 20 | 40 | 60 | 80 | 99 | 118 |
| 55 | 9234 | 21 | 42 | 63 | 84 | 104 | 124 |
| 60 | 9126 | 22 | 43 | 65 | 86 | 107 | 127 |
| 65 | 9013 | 22 | 45 | 67 | 88 | 109 | 130 |
| 70 | 8892 | 22 | 45 | 68 | 90 | 112 | 133 |
| 75 | 8765 | 23 | 46 | 68 | 91 | 113 | 135 |
| 80 | 8631 | 23 | 47 | 70 | 92 | 115 | 137 |
| 85 | 8488 | 23 | 47 | 70 | 93 | 116 | 139 |
| 90 | 8332 | 24 | 48 | 71 | 94 | 117 | 140 |

TABLE VIII—Continued.

| Per cent. by vol. of pure alcohol, at 60° Fahr. | Specific gravity at 60° Fahrenheit. | *Decrease* of the specific gravities, corresponding to the various per cents., at 60° Fahrenheit, for the following degrees of Fahrenheit's thermometer. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 65° | 70° | 75° | 80° | 85° | 90° | 95° | 100° |
| 0 | 9991 | 5 | 11 | 17 | 24 | 32 | 40 | 50 | 60 |
| 5 | 9919 | 5 | 11 | 18 | 25 | 33 | 42 | 51 | 62 |
| 10 | 9857 | 6 | 13 | 20 | 29 | 37 | 47 | 57 | 68 |
| 15 | 9802 | 7 | 15 | 25 | 34 | 44 | 55 | 67 | 79 |
| 20 | 9751 | 9 | 19 | 30 | 41 | 53 | 66 | 79 | 93 |
| 25 | 9700 | 11 | 24 | 36 | 50 | 63 | 78 | 93 | 109 |
| 30 | 9646 | 14 | 28 | 43 | 59 | 75 | 91 | 108 | 125 |
| 35 | 9583 | 17 | 33 | 50 | 68 | 86 | 104 | 122 | 141 |
| 40 | 9510 | 18 | 37 | 56 | 75 | 94 | 114 | 134 | 154 |
| 45 | 9427 | 20 | 40 | 60 | 80 | 101 | 122 | 143 | 164 |
| 50 | 9335 | 21 | 42 | 63 | 84 | 106 | 128 | 150 | 173 |
| 55 | 9234 | 22 | 43 | 65 | 87 | 109 | 132 | 155 | 178 |
| 60 | 9126 | 22 | 44 | 67 | 90 | 113 | 136 | 159 | 183 |
| 65 | 9013 | 22 | 45 | 68 | 92 | 115 | 138 | 162 | 187 |
| 70 | 8892 | 23 | 46 | 69 | 93 | 117 | 141 | 165 | 190 |
| 75 | 8765 | 23 | 46 | 70 | 94 | 119 | 143 | 167 | 192 |
| 80 | 8631 | 23 | 47 | 71 | 96 | 120 | 144 | 169 | 194 |
| 85 | 8488 | 24 | 48 | 72 | 96 | 121 | 145 | 170 | 195 |
| 90 | 8332 | 24 | 48 | 72 | 97 | 121 | 146 | 171 | 196 |

59. The specific gravities in the two preceding tables are absolute; it is often, however, more convenient to use such as are indicated directly with glass vessels or hydrometers, and which are given in the next table.

## TABLE IX.

*Apparent specific gravities indicated at various temperatures by means of glass instruments.*

| Per ct. of alcohol at 60° Fahr. | Temperature. | | | | | |
|---|---|---|---|---|---|---|
| | 30° F. | 35° F. | 40° F. | 45° F. | 50° F. | 55° F. |
| 0 | 9994 | 9997 | 9997 | 9998 | 9997 | 9994 |
| 5 | 9924 | 9926 | 9926 | 9926 | 9925 | 9922 |
| 10 | 9868 | 9869 | 9868 | 9867 | 9865 | 9861 |
| 15 | 9823 | 9822 | 9820 | 9817 | 9813 | 9807 |
| 20 | 9786 | 9782 | 9777 | 9772 | 9766 | 9759 |
| 25 | 9752 | 9745 | 9737 | 9729 | 9720 | 9709 |
| 30 | 9715 | 9705 | 9694 | 9683 | 9671 | 9658 |
| 35 | 9668 | 9655 | 9641 | 9627 | 9612 | 9598 |
| 40 | 9609 | 9594 | 9577 | 9560 | 9544 | 9527 |
| 45 | 9535 | 9518 | 9500 | 9482 | 9464 | 9445 |
| 50 | 9449 | 9431 | 9413 | 9393 | 9374 | 9354 |
| 55 | 9354 | 9335 | 9316 | 9295 | 9275 | 9254 |
| 60 | 9249 | 9230 | 9210 | 9189 | 9168 | 9147 |
| 65 | 9140 | 9120 | 9099 | 9078 | 9056 | 9034 |
| 70 | 9021 | 9001 | 8980 | 8958 | 8936 | 8913 |
| 75 | 8896 | 8875 | 8854 | 8832 | 8810 | 8787 |
| 80 | 8764 | 8743 | 8721 | 8699 | 8676 | 8653 |
| 85 | 8623 | 8601 | 8579 | 8556 | 8533 | 8510 |
| 90 | 8469 | 8446 | 8423 | 8401 | 8379 | 8355 |
| If brass instruments are used, *subtract*— | | | | | | |
| | 5 | 4 | 3 | 2 | 2 | 1 |

TABLE IX—Continued.

| Per ct. of alcohol at 60° Fahr. | Temperature. | | | | | |
|---|---|---|---|---|---|---|
| | 60° F. | 65° F. | 70° F. | 75° F. | 80° F. | 85° F. |
| 0 | 9991 | 9987 | 9981 | 9976 | 9970 | 9962 |
| 5 | 9919 | 9915 | 9909 | 9903 | 9897 | 9889 |
| 10 | 9857 | 9852 | 9845 | 9839 | 9831 | 9823 |
| 15 | 9802 | 9796 | 9788 | 9779 | 9771 | 9761 |
| 20 | 9751 | 9743 | 9733 | 9723 | 9713 | 9701 |
| 25 | 9700 | 9690 | 9678 | 9666 | 9653 | 9640 |
| 30 | 9646 | 9633 | 9619 | 9605 | 9590 | 9574 |
| 35 | 9583 | 9567 | 9551 | 9535 | 9518 | 9500 |
| 40 | 9510 | 9493 | 9474 | 9456 | 9438 | 9419 |
| 45 | 9427 | 9408 | 9388 | 9369 | 9350 | 9329 |
| 50 | 9335 | 9315 | 9294 | 9274 | 9253 | 9232 |
| 55 | 9234 | 9213 | 9192 | 9171 | 9150 | 9128 |
| 60 | 9126 | 9105 | 9083 | 9061 | 9039 | 9016 |
| 65 | 9013 | 8992 | 8969 | 8947 | 8924 | 8901 |
| 70 | 8892 | 8870 | 8847 | 8825 | 8801 | 8778 |
| 75 | 8765 | 8743 | 8720 | 8697 | 8673 | 8649 |
| 80 | 8631 | 8609 | 8585 | 8562 | 8538 | 8514 |
| 85 | 8488 | 8465 | 8441 | 8418 | 8394 | 8370 |
| 90 | 8332 | 8309 | 8285 | 8262 | 8238 | 8214 |
| If brass instruments are used, *add* to the above— | | | | | | |
| | 0 | 1 | 2 | 2 | 3 | 4 |

60. In the first column of each of the above tables, the numbers refer exclusively to columns measured at 60° Fahrenheit. They, therefore, serve only when the quantity of spirit in a cask, or vessel, is determined at 60°; but, if the liquor has been proved and the cask guaged, say at 80°, we must make a calculation to ascertain what number of gallons should pay duty, as alcohol of 60°, at any given legal rate per gallon. The data for this calculation are furnished by TABLES VIII. and IX.

Suppose, for example, the cask to contain, at 80° Fahrenheit, 200 gallons of spirit; for which a glass hydrometer gives the apparent specific gravity 9253, or one of metal, 9256. Then we find in TABLE IX. the strength to be 50 per cent. of the volume, which the liquor would occupy at 60°; and TABLE VIII. gives this volume, or rather the ratio of the volume at 80° to that at 60°; these volumes being inversely proportional to the densities 9251 and 9335. We must, therefore, multiply the 200 gallons by the ratio of these densities, to obtain the quantity, of which 50 per cent. should pay duty, as alcohol of 60° Fahrenheit. Thus we have

$$200 \,.\, \tfrac{9335}{9251} \times 0.50 = 99.09,$$

the number of gallons required.

These calculations are simple, but the following table renders them unnecessary.

## TABLE X.

| Per cent. of alcohol. | Temperatures. | | | | | |
|---|---|---|---|---|---|---|
| | 30° F. | 35° F. | 40° F. | 45° F. | 50° F. | 55° F. |
| 0 | 9994 | 9997 | 9997 | 9998 | 9997 | 9994 |
| 5 | 9924 | 9926 | 9926 | 9926 | 9925 | 9922 |
| 10 | 9868 | 9869 | 9868 | 9867 | 9865 | 9861 |
| 15 | 9823 | 9822 | 9820 | 9817 | 9813 | 9807 |
| 20 | 9786 | 9782 | 9777 | 9772 | 9766 | 9759 |
| 25 | 9753 | 9746 | 9738 | 9729 | 9720 | 9709 |
| 30 | 9717 | 9707 | 9695 | 9684 | 9672 | 9659 |
| 35 | 9671 | 9658 | 9644 | 9629 | 9614 | 9599 |
| 40 | 9615 | 9598 | 9581 | 9563 | 9546 | 9528 |
| 45 | 9544 | 9525 | 9506 | 9486 | 9467 | 9447 |
| 50 | 9460 | 9440 | 9120 | 9399 | 9378 | 9356 |
| 55 | 9368 | 9347 | 9325 | 9302 | 9279 | 9256 |
| 60 | 9267 | 9245 | 9222 | 9198 | 9174 | 9150 |
| 65 | 9162 | 9138 | 9113 | 9088 | 9063 | 9038 |
| 70 | 9046 | 9021 | 8996 | 8970 | 8944 | 8917 |
| 75 | 8925 | 8899 | 8873 | 8847 | 8820 | 8792 |
| 80 | 8798 | 8771 | 8744 | 8716 | 8688 | 8659 |
| 85 | 8663 | 8635 | 8606 | 8577 | 8547 | 8517 |
| 90 | 8517 | 8486 | 8455 | 8425 | 8395 | 8363 |

| Per cent. of alcohol. | Temperatures. | | | | | |
|---|---|---|---|---|---|---|
| | 60° F. | 65° F. | 70° F. | 75° F. | 80° F. | 85° F. |
| 0 | 9991 | 9987 | 9981 | 9976 | 9970 | 9962 |
| 5 | 9919 | 9915 | 9909 | 9903 | 9897 | 9889 |
| 10 | 9857 | 9852 | 9845 | 9839 | 9831 | 9823 |
| 15 | 9802 | 9796 | 9788 | 9779 | 9771 | 9761 |
| 20 | 9751 | 9743 | 9733 | 9722 | 9711 | 9700 |
| 25 | 9700 | 9690 | 9678 | 9665 | 9652 | 9638 |
| 30 | 9646 | 9632 | 9618 | 9603 | 9588 | 9572 |
| 35 | 9583 | 9566 | 9549 | 9532 | 9514 | 9495 |
| 40 | 9510 | 9491 | 9472 | 9452 | 9433 | 9412 |
| 45 | 9427 | 9406 | 9385 | 9364 | 9342 | 9320 |
| 50 | 9335 | 9313 | 9290 | 9267 | 9244 | 9221 |
| 55 | 9234 | 9211 | 9187 | 9163 | 9139 | 9114 |
| 60 | 9126 | 9102 | 9076 | 9051 | 9026 | 9000 |
| 65 | 9013 | 8988 | 8962 | 8936 | 8909 | 8882 |
| 70 | 8892 | 8866 | 8839 | 8812 | 8784 | 8756 |
| 75 | 8765 | 8738 | 8710 | 8681 | 8651 | 8622 |
| 80 | 8631 | 8602 | 8573 | 8544 | 8514 | 8483 |
| 85 | 8488 | 8458 | 8427 | 8396 | 8365 | 8333 |
| 90 | 8382 | 8300 | 8268 | 8236 | 8204 | 8171 |

61. Should a brass hydrometer be used instead of one of glass, then either the series of numbers 5, 4, 3, 2, 2, 1, *subtractive*, or 0, 1, 2, 2, 3, 4, *additive*, as in TABLE IX., will give the correction to be applied to the numbers in this last table; the argument of which correction is the observed temperature of the liquor.

In constructing the table just given, Tralles assumes that both the strength and the quantity of the liquor are determined at the same temperature. Should such not have been the case, it becomes necessary to make a calculation analogous to that given in the example above. It is, therefore, desirable, and to avoid errors in collecting duties, it should be required, that the liquor be both gauged and proved at the same time and same temperature.

If this be done, and table X. be interpolated for every integral number in the first column between 0 and 100, it will furnish all that is necessary for carrying out Messrs. Gilpin and Blagden's urgently recommended, "most simple, and equitable method of levying the duty on spirituous liquors, by considering rectified spirit (alcohol) as the true and only excisable matter." Such results form the basis of M. Gay Lussac's admirable table, used in the revenue of the French government, and entitled:* "A table of the richness in alcohol of spirituous liquors, giving the number of measures of alcohol of the temperature 15° c., (59° Fahrenheit,) which 100 measures of any spirituous liquor contain, for each indication of the hydrometer, and at every temperature between 0° and 30° cent."

The table lately recommended by a committee of the Royal Society, for adoption by the British government, (see § 42,) is also somewhat analogous to that of Gay Lussac; though objectionable, and much inferior even to the table of decimal multipliers of Gilpin and Blagden, to which it is equivalent, because it refers to a comparatively low and perfectly arbitrary *proof spirit*, combined with an artificial substitute for the technical *over proofs* and *under proofs*† of the British excise.

### *Third part of Tralles's report.*

62. Before the tables of the second part of Mr. Tralles's report can be used in practice, the specific gravity of the liquor under examination must be ascertained. He has therefore discussed, in the third part, the question: "how can the apparent specific gravity of a spirituous liquor be determined accurately?" and then treats of "alcoholmeters, their construction and their use."

63. As an instrument so delicate as a balance, if properly made, is liable to accident and consequent error in the hands of unskilful subordinate officers of the revenue, Tralles condemns its use for

* "Table de Richesse en Alcool des liquides spiritueux, donnant le nombre de litres d'alcool de 15°, que contiennent 100 litres d'un liquide spiritueux, pour chaque indication de l'alcoomètre, à toutes les temperatures de 0° à 30°."

† See Sen. Doc., No. 165, 28th Congress, 2d Session, p. 94, 95.

determining specific gravities, except in cases of dispute. And, even in such cases, he prefers and recommends either a hollow glass sphere to sink with various attached weights, or Fahrenheit's areometer, or his own *hydrostatic balance*, which closely resembles those of his pupil, the late Mr. Hassler, and which is also a modification of the instrument of Fahrenheit, just mentioned. A detailed explanation of the mode of using, and the calculations required for these instruments, are given in the report, which may here be omitted.

Of hydrometers graduated to indicate apparent specific gravities directly, Tralles says nothing; he, however, mentions a steelyard constructed for this purpose, but not in terms of decided approbation.

64. The calculations required by any exact method of taking specific gravities would always be inconvenient, and often accidental errors would be committed. Tralles, therefore, considered it necessary, for common use, that an instrument be employed which would dispense with all direct reference to specific gravities, and indicate the per cents. by volume of the first column of either of the preceding tables, which he had computed from the data of Messrs. Gilpin and Blagden. Such an instrument he deemed the more indispensable, "because it is not to be expected that subordinate officers will possess sufficient judgment and information to follow the rules and make the calculations here laid down as requisite; they must, therefore, use instruments and tables mechanically."

65. For the construction of the *alcoholometer*, or hydrometer indicating per cents. by volume of alcohol contained in any liquor, and for the corrections for temperature to be applied to the observed indications, the following tables were therefore computed.

At the temperature of 60° Fahrenheit, if the diameter of the stem be uniform, and the zero of the scale of the hydrometer be assumed to be the point to which it sinks in water of maximum density, (39.5° Fahrenheit, nearly,) the lengths of the different degrees of the graduated scale will correspond to the numbers given in table XI., hereto annexed:

TABLE XI.

*For alcoholometers at 60° Fahrenheit.*

| Per ct. of alcohol by volume. | Length of the part of the stem immersed. | Magnitude of the intervals. | Per ct. of alcohol by volume. | Length of the part of the stem immersed. | Magnitude of the intervals. |
|---|---|---|---|---|---|
| 0 | 9 | .. | 51 | 735 | 23 |
| 1 | 24 | 15 | 52 | 758 | 23 |
| 2 | 39 | 15 | 53 | 782 | 24 |
| 3 | 54 | 15 | 54 | 806 | 24 |
| 4 | 68 | 14 | 55 | 830 | 24 |
| 5 | 82 | 14 | 56 | 854 | 24 |
| 6 | 95 | 13 | 57 | 879 | 25 |
| 7 | 108 | 13 | 58 | 905 | 26 |
| 8 | 121 | 13 | 59 | 931 | 26 |
| 9 | 133 | 12 | 60 | 957 | 26 |
| 10 | 145 | 12 | 61 | 984 | 27 |
| 11 | 157 | 12 | 62 | 1011 | 27 |
| 12 | 169 | 12 | 63 | 1039 | 28 |
| 13 | 180 | 11 | 64 | 1067 | 28 |
| 14 | 191 | 11 | 65 | 1096 | 29 |
| 15 | 202 | 11 | 66 | 1125 | 29 |
| 16 | 213 | 11 | 67 | 1154 | 29 |
| 17 | 224 | 11 | 68 | 1184 | 30 |
| 18 | 235 | 11 | 69 | 1215 | 31 |
| 19 | 245 | 10 | 70 | 1246 | 31 |
| 20 | 256 | 10 | 71 | 1278 | 32 |
| 21 | 266 | 10 | 72 | 1310 | 32 |
| 22 | 277 | 11 | 73 | 1342 | 32 |
| 23 | 288 | 11 | 74 | 1375 | 33 |
| 24 | 299 | 11 | 75 | 1409 | 34 |
| 25 | 310 | 11 | 76 | 1443 | 34 |
| 26 | 321 | 11 | 77 | 1478 | 35 |
| 27 | 332 | 11 | 78 | 1514 | 36 |
| 28 | 344 | 12 | 79 | 1550 | 36 |
| 29 | 356 | 11 | 80 | 1587 | 37 |
| 30 | 367 | 12 | 81 | 1624 | 37 |
| 31 | 380 | 13 | 82 | 1662 | 38 |
| 32 | 393 | 13 | 83 | 1701 | 39 |
| 33 | 407 | 14 | 84 | 1740 | 39 |
| 34 | 420 | 13 | 85 | 1781 | 41 |
| 35 | 434 | 14 | 86 | 1823 | 42 |
| 36 | 449 | 15 | 87 | 1866 | 43 |
| 37 | 465 | 16 | 88 | 1910 | 44 |
| 38 | 481 | 16 | 89 | 1955 | 45 |
| 39 | 498 | 17 | 90 | 2002 | 47 |
| 40 | 515 | 17 | 91 | 2050 | 48 |
| 41 | 533 | 18 | 92 | 2099 | 49 |
| 42 | 551 | 18 | 93 | 2150 | 51 |
| 43 | 569 | 18 | 94 | 2203 | 53 |
| 44 | 588 | 18 | 95 | 2259 | 56 |
| 45 | 608 | 20 | 96 | 2318 | 59 |
| 46 | 628 | 20 | 97 | 2380 | 62 |
| 47 | 648 | 20 | 98 | 2447 | 67 |
| 48 | 669 | 21 | 99 | 2519 | 72 |
| 49 | 690 | 21 | 100 | 2597 | 78 |
| 50 | 712 | 22 | | | |

66. To graduate a hydrometer by means of the preceding table, it must be put successively into two liquids of known specific gravities, and at 60° Fahrenheit; one of which should be distilled water, and the other may be the strongest alcohol which can be readily procured, the specific gravity of which must be determined with great care. The point to which the instrument sinks in each being accurately observed, the intermediate space is to be divided into the number of equal parts indicated in the second column of the table, giving to the intervals between the traces in the graduation the relative numbers of parts required by the third column.

Should the stem of the hydrometer be variable in its diameter, for different portions, it is requisite to determine not only the extreme, but also several intermediate points, by means of liquids of known specific gravities, and to graduate the spaces between them according to the table, as in the construction of standard thermometers to eliminate errors due to irregularities in the bore of the tube employed. The artist will, therefore, find it advantageous to make the stem as uniform as possible; by attending to which he will not only avoid useless trouble, but render his work much more exact.

67. Hydrometers, constructed according to the table just given, will indicate the real strengths of liquors only at the temperature of 60° Fahrenheit. To obtain the true per cent. by means of the apparent, when the temperature is different, the three following tables have been computed by Tralles; and they are not only convenient, but necessary. They are calculated to tenths of a per cent.; but, says Tralles, "it must not be expected that they will always be true to so nice a degree." The first of these tables, marked table XII., corresponds to table IX. of the preceding section; in it, therefore, the volume is supposed to be measured always at 60° Fahrenheit, but the strength to be ascertained at any other temperature; in tables XIII. and XIV., adapted one to glass hydrometers, and the other to those of brass, both the strength and the volume are supposed to have been determined at the same temperature; these tables, therefore, correspond to table X., and are those which should be used by revenue officers.

## TABLE XII.

| Indications of a glass hydrometer at the temperatures. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30° F. | 35° F. | 40° F. | 45° F. | 50° F. | 55° F. | 60° F. | 65° F. | 70° F. | 75° F. | 80° F. | 85° F. |
| — 0.2 | — 0.4 | — 0.4 | — 0.5 | — 0.4 | — 0.2 | 0 | 0.2 | 0.6 | 1.0 | 1.4 | 1.9 |
| + 4.6 | 4.5 | 4.5 | 4.5 | 4.6 | 4.8 | 5 | 5.3 | 5.8 | 6.2 | 6.7 | 7.3 |
| 9.1 | 9.0 | 9.1 | 9.2 | 9.3 | 9.7 | 10 | 10.4 | 11.0 | 11.6 | 12.3 | 13.0 |
| 13.0 | 13.1 | 13.3 | 13.5 | 13.9 | 14.5 | 15 | 15.6 | 16.3 | 17.1 | 18.0 | 19.0 |
| 16.5 | 16.9 | 17.4 | 17.8 | 18.5 | 19.2 | 20 | 20.8 | 21.8 | 22.8 | 23.8 | 24.9 |
| 19.9 | 20.6 | 21.4 | 22.2 | 23.0 | 24.1 | 25 | 25.9 | 27.0 | 28.2 | 29.4 | 30.5 |
| 23.5 | 24.5 | 25.7 | 26.6 | 27.7 | 28.8 | 30 | 31.1 | 32.2 | 33.4 | 34.5 | 35.7 |
| 28.0 | 29.2 | 30.4 | 31.6 | 32.7 | 33.8 | 35 | 36.2 | 37.3 | 38.4 | 39.5 | 40.6 |
| 33.0 | 34.2 | 35.4 | 36.7 | 37.8 | 39.0 | 40 | 41.1 | 42.2 | 43.3 | 44.3 | 45.4 |
| 38.4 | 39.6 | 40.7 | 41.8 | 42.9 | 43.9 | 45 | 46.1 | 47.1 | 48.2 | 49.2 | 50.3 |
| 43.7 | 44.7 | 45.8 | 46.9 | 47.9 | 49.0 | 50 | 51.0 | 52.0 | 53.0 | 54.0 | 55.1 |
| 49.0 | 50.0 | 51.0 | 52.0 | 53.0 | 54.0 | 55 | 54.9 | 56.9 | 57.9 | 58.9 | 59.9 |
| 54.2 | 55.2 | 56.2 | 57.1 | 58.1 | 59.0 | 60 | 60.9 | 61.9 | 62.9 | 63.8 | 64.9 |
| 59.4 | 60.3 | 61.2 | 62.2 | 63.1 | 64.0 | 65 | 65.9 | 66.8 | 67.7 | 68.6 | 69.6 |
| 64.6 | 65.5 | 66.4 | 67.3 | 68.2 | 69.1 | 70 | 70.8 | 71.7 | 72.6 | 73.5 | 74.5 |
| 69.8 | 70.7 | 71.5 | 72.4 | 73.3 | 74.2 | 75 | 75.8 | 76.7 | 77.6 | 78.4 | 79.3 |
| 75.0 | 75.8 | 76.6 | 77.5 | 78.4 | 79.2 | 80 | 80.8 | 81.7 | 82.4 | 83.2 | 84.1 |
| 80.3 | 81.1 | 81.8 | 82.6 | 83.5 | 84.3 | 85 | 85.7 | 86.5 | 87.3 | 88.0 | 88.8 |
| 85.6 | 86.4 | 87.1 | 87.9 | 88.6 | 89.3 | 90 | 90.7 | 91.4 | 92.0 | 92.7 | 93.4 |

## TABLE XIII.

*For finding the real per cent. of alcohol from the indications of the hydrometer at different temperatures.*

| True per cent. of alcohol. | Indications of a glass hydrometer at the temperatures of— | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30° F. | 35° F. | 40° F. | 45° F. | 50° F. | 55° F. | 65° F. | 70° F. | 75° F. | 80° F. | 85° F. |
| 0 | — 0.2 | — 0.4 | — 0.4 | — 0.5 | — 0.4 | — 0.2 | 0.2 | 0.6 | 1.0 | 1.4 | 1.9 |
| 5 | 4.6 | 4.5 | 4.5 | 4.5 | 4.6 | 4.8 | 5.3 | 5.8 | 6.2 | 6.7 | 7.3 |
| 10 | 9.1 | 9.0 | 9.1 | 9.2 | 9.3 | 9.7 | 10.4 | 11.0 | 11.6 | 12.3 | 13.0 |
| 15 | 13.0 | 13.1 | 13.3 | 13.6 | 14.1 | 14.5 | 15.6 | 16.3 | 17.1 | 18.0 | 19.0 |
| 20 | 16.5 | 16.9 | 17.4 | 17.9 | 18.5 | 19.2 | 20.8 | 21.8 | 22.9 | 23.9 | 25.0 |
| 25 | 19.8 | 20.5 | 21.3 | 22.2 | 23.0 | 24.1 | 25.9 | 27.1 | 28.3 | 29.5 | 30.7 |
| 30 | 23.3 | 24.3 | 25.5 | 26.5 | 27.6 | 28.8 | 31.2 | 32.3 | 33.5 | 34.6 | 35.9 |
| 35 | 27.7 | 28.9 | 30.2 | 31.4 | 32.6 | 33.8 | 36.3 | 37.5 | 38.6 | 39.7 | 40.9 |
| 40 | 32.5 | 33.8 | 35.1 | 36.5 | 37.7 | 38.9 | 41.2 | 42.4 | 43.5 | 44.6 | 45.8 |
| 45 | 37.8 | 39.1 | 40.3 | 41.5 | 42.7 | 43.8 | 46.2 | 47.3 | 48.5 | 49.6 | 50.8 |
| 50 | 43.1 | 44.2 | 45.4 | 46.6 | 47.7 | 48.9 | 51.1 | 52.2 | 53.4 | 54.5 | 55.6 |
| 55 | 48.3 | 49.4 | 50.5 | 51.6 | 52.8 | 53.9 | 56.1 | 57.2 | 58.3 | 59.4 | 60.5 |
| 60 | 53.4 | 54.5 | 55.6 | 56.7 | 57.8 | 58.9 | 61.1 | 62.2 | 63.3 | 64.4 | 65.5 |
| 65 | 58.4 | 59.5 | 60.6 | 61.7 | 62.8 | 63.9 | 66.0 | 67.1 | 68.2 | 69.3 | 70.4 |
| 70 | 63.5 | 64.6 | 65.7 | 66.8 | 67.9 | 69.0 | 71.0 | 72.1 | 73.2 | 74.3 | 75.4 |
| 75 | 68.6 | 69.7 | 70.7 | 71.8 | 72.9 | 74.0 | 76.0 | 77.1 | 78.2 | 79.2 | 80.3 |
| 80 | 73.7 | 74.8 | 75.8 | 76.9 | 78.0 | 79.0 | 81.0 | 82.1 | 83.1 | 84.1 | 85.2 |
| 85 | 78.8 | 79.8 | 80.9 | 81.9 | 83.0 | 84.0 | 86.0 | 87.0 | 88.0 | 89.0 | 90.0 |
| 90 | 84.0 | 85.1 | 86.1 | 87.1 | 88.1 | 89.1 | 91.0 | 91.9 | 92.8 | 93.7 | 94.6 |

## TABLE XIV.

*To find the real per cent. of alcohol from the apparent.*

| Real per cent. of alcohol. | Apparent per cents. of alcohol as indicated by brass instruments at the temperatures. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30° F. | 35° F. | 40° F. | 45° F. | 50° F. | 55° F. | 65° F. | 70° F. | 75° F. | 80° F. | 85° F. |
| 0 | — 0.1 | — 0.1 | — 0.2 | — 0.3 | — 0.3 | — 0.2 | 0.2 | 0.5 | 0.9 | 1.2 | 1.7 |
| 5 | 5.0 | 4.8 | 4.7 | 4.8 | 4.7 | 4.8 | 5.2 | 5.6 | 6.1 | 6.5 | 7.0 |
| 10 | 9.5 | 9.4 | 9.4 | 9.4 | 9.5 | 9.7 | 10.3 | 10.8 | 11.4 | 12.0 | 12.6 |
| 15 | 13.5 | 13.5 | 13.6 | 13.7 | 14.0 | 14.6 | 15.5 | 16.2 | 17.0 | 17.7 | 18.6 |
| 20 | 17.0 | 17.3 | 17.7 | 18.1 | 18.7 | 19.3 | 20.7 | 21.6 | 22.7 | 23.7 | 24.6 |
| 25 | 20.3 | 20.9 | 21.6 | 22.4 | 23.3 | 24.2 | 25.8 | 26.9 | 28.1 | 29.2 | 30.3 |
| 30 | 23.8 | 24.7 | 25 8 | 26.8 | 27.8 | 28.9 | 31.1 | 32.2 | 33.3 | 34.4 | 35.5 |
| 35 | 28.2 | 29.3 | 30.4 | 31.6 | 32.8 | 33.9 | 36.2 | 37.3 | 38.4 | 39.5 | 40.7 |
| 40 | 32.9 | 34.1 | 35.4 | 36.7 | 37.9 | 39.0 | 41.1 | 42.2 | 43.4 | 44.5 | 45.6 |
| 45 | 38.1 | 39.3 | 40.4 | 41.6 | 42.7 | 43.9 | 46.1 | 47.2 | 48.3 | 49.4 | 50.5 |
| 50 | 43.4 | 44.5 | 45.6 | 46.7 | 47.8 | 48.9 | 51.1 | 52.2 | 53.3 | 54.4 | 55.5 |
| 55 | 48.5 | 49.6 | 50.7 | 51.8 | 52.9 | 54.0 | 56.0 | 57.1 | 58.2 | 59.3 | 60.4 |
| 60 | 53.6 | 54.6 | 55.7 | 56.8 | 57.8 | 58.9 | 61.0 | 62.1 | 63.2 | 64.3 | 65.3 |
| 65 | 58.6 | 59.7 | 60.7 | 61.8 | 62.8 | 63.9 | 66.0 | 67.1 | 68.1 | 69.2 | 70.2 |
| 70 | 63.7 | 64.8 | 65.8 | 66.9 | 67.9 | 69.0 | 71.0 | 72.1 | 73.1 | 74.2 | 75.2 |
| 75 | 68.8 | 69.8 | 70.9 | 71.9 | 72.9 | 74.0 | 76.0 | 77.0 | 78.1 | 79.1 | 80.1 |
| 80 | 73.9 | 74.9 | 75.9 | 76.9 | 78.0 | 79.0 | 81.0 | 82.0 | 83.0 | 84.0 | 85.0 |
| 85 | 79.0 | 80.0 | 81.0 | 82.0 | 83.0 | 84.0 | 86.0 | 87.0 | 88.0 | 88.9 | 89.9 |
| 90 | 84.2 | 85.2 | 86.2 | 87.2 | 88.1 | 89.1 | 90.9 | 91.9 | 92.8 | 93.7 | 94.5 |

68. As perfect accuracy in ascertaining the strengths of liquors is not requisite or attainable in ordinary operations, Tralles recommends that one half of a per cent. should be the smallest fraction taken into consideration, and that two other tables be calculated, by interpolation, in place of TABLE XIII. and TABLE XIV., for every half of a per cent., and each degree of the thermometer to be used by the revenue officers.

To glass hydrometers he gives decided preference, as entirely free from liability to falsification; while at the same time they may be made of sufficient strength. Metallic hydrometers, in his opinion, should be frequently inspected if in use, because their accuracy is apt to be impaired, not only by bruises, but by corrosion, and the consequent change of weight.

69. The preceding is a very complete abstract of Tralles's report, and it will serve to show with what care his work was done. The report contains an account of some experiments made with the view of ascertaining the influence of such impurities as are contained in genuine liquors; besides numerous illustrative examples of the mode of using each table, and the calculations to be made when the observed numbers are not immediately expressed. The whole constitutes a very elaborate and able document, worthy of the praise which has been so generally bestowed on it.

### *Other researches in Germany.*

70. *In Austria by Meissner.*—The results obtained by Meissner, from his own private experiments,* though very imperfect and unsatisfactory, seem to have been adopted as fundamental data in the revenue of the Austrian government. In order that what I may say of his investigations may have as much authenticity as possible, I will give a strict translation of Meissner's own account of them.

71. He first remarks "that the tables of Richter and Lowitz are, in many points, incorrect, which must not be ascribed so much to faults of experiment as to the circumstance that they were both led into error, by supposing a regular geometrical progression to exist in the law of dilatation of such mixtures.

Richter, by means of a few points only, calculated all the remaining terms of his table; and Lowitz so firmly believed the law of regular progression, that he doubted his own facts, the results of varied and multiplied experiments, and applied to them hypothetical corrections required by the assumed law; thus deviating from the truth. No person can more readily excuse such mistakes than one who has made similar researches, and who has felt how easy it is to be led astray in a new field of inquiry by preconceived notions. Of this truth I am so convinced, that I am confi-

* Die aräometrie in ihrer anwendung auf Chemie und Technik, von P. T. Meissner, Wien, 1816, p. 81, 83.

dent I should have fallen into the same error, if not forewarned by the errors of others which I discovered in the use of their tables, to which I had frequent occasion to refer, and which induced me to make new experiments."

"Guided by the previous labors of the above mentioned chemists, I made a series of experiments in the year 1806, but did not publish them before 1812. By Richter's method of distillation with chloride of calcium, I prepared a normal alcohol, of the specific gravity 0.791 at 16° R. Of this liquid I then made two sets of mixtures with water: one by weight, and the other by volume; varying their proportions, successively, by 5 per cent. After twenty-four hours of rest, the specific gravities were taken at 16° R., and arranged in tabular form, as shown in TABLE XV. In these experiments I used the temperature 16° R. in order to compare my results more readily with those of Richter and Lowitz; and in making the mixtures by volume, to avoid error, I first calculated from the specific gravity of each liquid the weight corresponding to the required volume, and then determined the latter by means of the balance, instead of measuring it directly. On these results I also founded the construction of my *alcoholometer*, which indicates per cents by volume, and by weight, of pure alcohol contained in any spirituous liquor."

72. The tables of Tralles were published in 1811, but Meissner seems to have known nothing of them, or of those of Messrs. Gilpin and Blagden, until he had finished the above-mentioned work. Subsequently, in 1814, when he obtained Tralles's report, and compared the results with his own, he found that, "in general, they agreed, having only some slight and discontinuous deviations. But to remove even these small differences, if possible, a new series of experiments were made."

"As the first experiments were, by chance, performed with alcohol obtained from wine, the new series were made with spirit prepared from whiskey; the specific gravities were taken at 14° R.; and the results were arranged in a table, (TABLE XVI.;) to which I shall refer for the determination of the true strengths of spirituous liquors, though it will readily be seen that the former table may be used for the same purpose without important errors being thus produced."

TABLE XV.

| Per cent. | Specific gravity at 16° R. | | Per cent. | Specific gravity at 16° R. | |
|---|---|---|---|---|---|
| | By weight. | By volume. | | By weight. | By volume. |
| 100 | 791 | 791 | 45 | 926 | 938 |
| 95 | 805 | 809 | 40 | 937 | 947 |
| 90 | 818 | 824 | 35 | 947 | 955 |
| 85 | 831 | 839 | 30 | 955 | 963 |
| 80 | 843 | 854 | 25 | 963 | 969 |
| 75 | 856 | 867 | 20 | 970 | 975 |
| 70 | 868 | 880 | 15 | 977 | 981 |
| 65 | 880 | 893 | 10 | 984 | 987 |
| 60 | 892 | 906 | 5 | 992 | 993 |
| 55 | 904 | 917 | 0 | 1000 | 1000 |
| 50 | 915 | 928 | | | |

TABLE XVI.

| Per cent. | Specific gravity at 14° R. | | Per cent. | Specific gravity at 14° R. | |
|---|---|---|---|---|---|
| | By weight. | By volume. | | By weight. | By volume. |
| 100 | 7932 | 7932 | 45 | 9286 | 9404 |
| 95 | 8074 | 8114 | 40 | 9391 | 9495 |
| 90 | 8225 | 8286 | 35 | 9486 | 9580 |
| 85 | 8353 | 8427 | 30 | 9578 | 9643 |
| 80 | 8470 | 8566 | 25 | 9647 | 9700 |
| 75 | 8590 | 8695 | 20 | 9712 | 9756 |
| 70 | 8704 | 8833 | 15 | 9775 | 9803 |
| 65 | 8831 | 8958 | 10 | 9830 | 9859 |
| 60 | 8948 | 9075 | 5 | 9914 | 9929 |
| 55 | 9060 | 9191 | 0 | 10000 | 10000 |
| 50 | 9173 | 9303 | | | |

73. With reference to the results of this second series of experiments Meissner says: "I had full confidence, both in the tables of Professor Tralles and in the correctness of my own previcus investigations, therefore the discrepancies between them were to me incomprehensible. It would be going beyond my prescribed limits to relate the whole series of my subsequent experiments, but a brief statement of the conclusions to which they lead may not be out of place. They tend to show:"

"1. That an opinion formerly expressed by me is probably correct, viz.: that the several varieties of alcohol which are made from different vegetable substances, or under different circumstances of fermentation, by no means possess the same properties, as heretofore supposed, but vary both in taste and smell, and may also give different specific gravities when similarly combined with water; for slight variations in the law of dilatation were given by these different products of vinous fermentation; and it was evident that the

deviations, though generally very small, were greatest between alcohol made from whiskey and that from wine."

"2d. That some kinds of alcohol by distillation over alkalies or muriate of lime are very quickly brought to the assumed specific gravity of pure alcohol, 0.791 at 16° R.; while others require many repetitions of the process; and some cannot be brought to that degree at all."

"Whether these results are due to differences in proportion of the constituent elements, as I firmly believe, or to intermixture with vegetable oils; or to the absence or presence of a small quantity of ether; and, in the latter case, in what manner, the formation of this ether can be explained, are questions which I leave others to decide."

"It is sufficient if we are enabled to perceive how it may happen that so many excellent chemists contend that alcohol of the specific gravity 0.791 at 16° R. does not exist; and also why, in the most exact experiments, slight deviations are inevitable."

74. It may be observed that Meissner makes no mention of the degree of care taken in determining either the specific gravities or the temperatures of his mixtures; and his ready mode of explaining away all discrepancies between his own work and that of others, by asserting that the varieties of alcohol obtained by different processes or from dissimilar substances are not identical, is set aside, both by the established facts of more modern chemistry, and by the remarkable coincidence of the specific gravities obtained by Messrs. Gilpin and Blagden for mixtures made with alcohol distilled from rum, and those determined with equal care by Delezennes, who used absolute alcohol prepared from wine by distillation with chloride of calcium. (See section 82.) We must, therefore, ascribe any discrepancies between Meissner's work and that of the persons just mentioned, rather to want of skill and care, or to errrors on his part, than to differences in the alcohol. In (section 107) I have compared the fundamental data of Meissner with those of Tralles and Gay Lussac, and thus shown that they do not possess particular merit.

I may here add, that the statement of Meissner, "that slight variations of the law of dilatation were given by these different products of vinous fermentation" does not seem to have been justified. For experiments made only at two temperatures not very remote from each other, 14° and 16° R., certainly could not indicate a law for temperatures generally.

75. Whether similar and more exact researches than those of Tralles or Meissner have since been made, either for private purposes or by authority of any of the numerous governments of Germany, I have found no means of ascertaining. But it is highly improbable that such should have been the fact, or mention would have been made of it in the excellent "*Handwörterbuch der Chemie*," of Liebig, Wöhler and Poggendorff, to which I have had repeatedly to refer.

*Experiments in Russia.*

76. *Lowitz's results.*—Of these I can add but little to what has been already given in the preceding abstracts of the papers of Tralles and Meissner, (sections 49 and 71;) because I have been unable to procure the book in which Lowitz published his researches, (Crell's Chem. Annal., vol. 1, 1796.) As reference is often made, however, to his table, I here insert it as taken from Poggendorff's article on alcoholometry,* but somewhat abridged:

TABLE XVII.

| Per cent. | Sp. grav. | Per cent. | Sp. grav. | Per cent. | Sp. grav. | Per cent | Sp. grav. |
|---|---|---|---|---|---|---|---|
| 100 | 791 | 75 | 856 | 50 | 914 | 25 | 965 |
| 95 | 805 | 70 | 868 | 45 | 925 | 20 | 973 |
| 90 | 818 | 65 | 880 | 40 | 936 | 15 | 980 |
| 85 | 831 | 60 | 892 | 35 | 946 | 10 | 987 |
| 80 | 844 | 55 | 903 | 30 | 956 | 5 | 994 |

In this table the per cents are by weight, and the specific gravities are supposed to be taken at 16° R., water being unity at the same temperature.

77. *Muncke's experiments* —A very elaborate and skilful series of researches, relative to the dilatation of liquids, made with thermometric tubes by Muncke, has been published in the transactions of the academy of St. Petersburgh.† To those for water, as well as to Hällstrom's calculations of their probable results, I have had occasion to refer both in my former report (page 82) and in the appendix herewith submitted.

Had not Muncke neglected to examine the fixed points of his thermometers, these researches might be considered very perfect; but that oversight has been committed by other observers, with the exception of M. Despretz; and similar errors, therefore, exist in their several results.

Among the tables of Muncke, there is one for the expansion of alcohol, of the specific gravity 0.8062, at 0° cent., water being unity at its maximum density. The calculated volumes of which table have been deduced from the formula:

$$\Delta V = 0.0010151148848\, t + 0.00000308840829\, t^2 - 0.0000000192458568\, t^3;$$

which gives a maximum at 89.5° c, or 127.°3 F., below zero.

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* Handworterb. d. Chem., vol. 1, page 214.
† Mém. présent. à l'Acad. de St. Petersb., par div. Savans t. 1 et 2.

TABLE XVIII.

*Dilatation of pure alcohol.*

| Temp. | Volume. | | Temp. | Volume. | |
|---|---|---|---|---|---|
| | Calculated. | Observed. | | Calculated. | Observed. |
| —15° C. | 0.9855331 | 0.9851728 | +14° C. | 1.0147641 | 1.0147368 |
| —10 | 0.9901769 | 0.9899009 | 16 | 69536 | 68808 |
| — 5 | 0.9950040 | 0.9949189 | 18 | 91605 | 90674 |
| 0 | 1.0000000 | 1.0000000 | 20 | 1.0213837 | 1.0212752 |
| + 1 | 10182 | 10719 | 22 | 36224 | 33893 |
| 2 | 20424 | 21021 | 25 | 70074 | 67491 |
| 3 | 30726 | 31575 | 30 | 1.0327134 | 1.0322457 |
| 4 | 41086 | 42463 | 35 | 84872 | 79702 |
| 5 | 51504 | 53185 | 40 | 1.0443143 | 1.0436746 |
| 6 | 61977 | 63071 | 45 | 1.0501804 | 1.0496608 |
| 7 | 72505 | 73585 | 50 | 60710 | 1.0557882 |
| 8 | 83087 | 84166 | 55 | 1.0619717 | 1.0619054 |
| 9 | 93722 | 94823 | 60 | 78681 | 82757 |
| 10 | 1.0104407 | 1.0105547 | 65 | 1.0737456 | 1.0746065 |
| 11 | 15143 | 16215 | 70 | 1.0796899 | 1.0811729 |
| 12 | 25929 | 26885 | | | |

*Researches in France.*

78. Although investigations, having for their object the more exact determination of the chemical properties of vinous and alcoholic liquors, were made by several of the distinguished chemists of France, no careful and complete series of experiments, with reference to the practical use of specific gravities for ascertaining the strengths of liquors, seems to have been made in that country until about the year 1820. At that time, the French government determined to alter its defective system of levying duties on spirits, based upon the arbitrary scale of Cartier's hydrometer, and to render it perfectly just by making the duty to be paid by any liquor proportional to its real value. The scientific men of the country were induced, by this circumstance, to consider the subject and to offer plans, which were submitted to the Academy of Sciences at Paris for a decision. MM. Francœur, Delezennes, and Gay Lussac devoted much time and attention to the matter; and brought forward, about the same time, three independent and excellent methods of attaining the desired end.

79. M. Francœur proposed the adoption of his "*aréomètre centigrade*," or the decimal hydrometer which I have fully discussed in my former report.* He performed no experiments to determine the specific gravities of mixtures of alcohol and water; but referred for these to the data of Messrs. Gilpin and Blagden; and, when the decision of the academy was pronounced in favor of the method of

* Sen. Doc. No. 165; 28th Cong. 2d Session, p. 52, et seq.

M. Gay Lussac, he dropped the subject. To give his own account of the matter:* "the administration submitted my memoir to the Academy for its advice. But, upon comparison of the method I proposed with that of M. Gay Lussac, more simple and more easy of application, the latter obtained the preference, very justly as I at once acknowledged. The favorable opinion given, with reference to my memoir, consoled me for its merited rejection, and I abandoned my researches."

80. M. Delezennes invented a hydrometer very similar to, and, indeed, almost identical with that of Francœur. The only difference being that the scale of the former was divided into 400 integral parts, but that of the latter into 200, *subdivided into halves* and *tenths*. This apparent identity becomes even mor. striking, if the reasons assigned by Delezennes for the selection of 400 degrees instead of 200 are taken into view. They are as follows:†

"The construction of the hydrometer should be independent of all comparisons; it should be based exclusively upon, and be derived from the uses to which it is to be applied; and *the division of the scale*, as it is arbitrary, *should conform to the decimal system*. Also, the instrument should be universal, or adapted to every case which may occur; one of the extremities of the scale should, therefore, correspond to a density a little less than that of the lightest liquid known, say to 0.700; and the other to a density somewhat greater than that of the heaviest liquid, except mercury, or to 2.000 nearly. The difference between these extremes is 1.300, of which 0.013 is the hundredth part. Now the instrument, to be useful, should have sufficient sensibility to render appreciable, from one degree of its scale to another, a mean difference of about 0.003. The scale must, therefore, be divided into at least 400 parts; each of which, to be appreciable, should have an extent of at least one millimetre; and the whole scale must, therefore, be 40 centimetres long."

81. By far the most valuable part of M. Delezennes' researches was, however, a very complete and exact series of experiments, made with a view of determining the relative specific gravities of different mixtures of alcohol and water, as a proper basis for the system designed for the use of the government. And as these experiments constitute the only comparative and independent results, of equal merit with those of Messrs. Gilpin and Blagden, which have been published in an authentic manner, and of which I possess any knowledge, they are entitled to particular attention: the more so, perhaps, because the success of Gay Lussac caused them to be neglected; without, at the same time, furnishing equivalent fundamental results as a substitute for them.

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* Francœur Memoire sur l'Areomètrie, p. 1. Paris, 1842.
† Journal de Physique, t. 94, p. 204.

82. The original memoir of Delezennes on mixtures of alcohol and water appeared in the transactions of the Society of Agriculture, Sciences and Arts of Lille, for the year 1823, a book not readily met with; I must, therefore, refer to the account of it given in Ferussac's Bulletin*, from which I have extracted the following table and brief remarks:

"The experiments of M. Delezennes have been made with extreme care. *Neither the alcohol, nor the water, was deprived of the air which those liquids usually contain*, and the mixtures were made, by weight, for every 20th part of alcohol; i. e., they varied successively five per cent. Their specific gravities were taken at the temperatures 0°, 18°, 36° and 54°, cent.; by weighing them in a thin bottle with a tight conical stopper. All the weighings, both for the mixtures and the specific gravities, were performed according to the method of double weighing, and the proper reductions were made, in every instance, for the loss of weight caused by the air, as well as for the state of the thermometer, barometer and hygrometer.

TABLE XIX.

| | Specific gravity of the mixture. | | | |
|---|---|---|---|---|
| | At 0° C. | At 18°. | At 36°. | At 54°. |
| 0 | 1.00000 | 0.99855 | 0.99351 | 0.98721 |
| 5 | 0.99130 | 0.98983 | 0.98520 | 97736 |
| 10 | 0.98504 | 0.98261 | 0.97684 | 96805 |
| 15 | 0.98067 | 0.97587 | 0.96853 | 96050 |
| 20 | 0.97596 | 0.96974 | 0.96084 | 95054 |
| 25 | 0.97145 | 0.96312 | 0.95254 | 94097 |
| 30 | 0.96579 | 0.95588 | 0.94395 | 93166 |
| 35 | 0.95886 | 0.94682 | 0.93453 | 92133 |
| 40 | 0.95066 | 0.93781 | 0.92402 | 91058 |
| 45 | 0.93994 | 0.92733 | 0.91303 | 0.89963 |
| 50 | 0.93047 | 0.91632 | 0.90259 | 0.88801 |
| 55 | 0.92039 | 0.90605 | 0.89044 | 0.87594 |
| 60 | 0.90909 | 0.89474 | 0.87962 | 0.86382 |
| 65 | 0.89791 | 0.88338 | 0.86763 | 0.85194 |
| 70 | 0.88619 | 0.87180 | 0.85582 | 0.84047 |
| 75 | 0.87496 | 0.85974 | 0.84386 | 0.82884 |
| 80 | 0.86325 | 0.84834 | 0.83191 | 0.81693 |
| 85 | 0.85111 | 0.83561 | 0.81975 | 0.80414 |
| 90 | 0.83840 | 0.82310 | 0.80722 | 0.79099 |
| 95 | 0.82522 | 0.80974 | 0.79385 | 0.77790 |
| 100 | 0.81190 | 0.79539 | 0.78013 | 0.76436 |

"By interpolation, Delezennes obtained the specific gravities for every single per cent., both by weight and by volume, but only for the temperatures indicated above. He also endeavored to discover the law of the densities in question; whether, for ex-

* Bulletin Univ. des Sciences Math. t. 8, p. 132.

ample, they may be considered functions of a mixture of alcohol and water at a maximum degree of condensation, mixed with an excess of alcohol, or of water, without diminution of volume; but he obtained no satisfactory results.

These researches were discontinued when the government adopted the system proposed by Gay Lussac; and they do not appear even to have been laid before the academy; probably by reason of their incomplete condition at the time of its decision.

83. *Researches of Gay Lussac.*—Before discussing the alcoholometer, and the tables for its use, which have have been constructed by this distinguished philosopher, and established by law, not only in France, but also in Sweden and Belgium, it may be well to give an account of some experiments made by him in 1816 on the dilatation of liquids,* which, probably, constitute part of the fundamental data upon which he based the above-mentioned instrument and tables. I say *probably*, because Gay Lussac has not published those data, as he certainly should have done, if he wished to place beyond doubt and conjecture, either the justice of the French revenue, or the truth and scientific merit of his own work.

84. The object of the experiments, to which reference is here made, was to discover, if possible, a general law of dilatation for liquids. Gay Lussac had been led to think that the principal cause of failure in all previous attempts of the kind was, that the liquids had not been placed under like physical circumstances. He, therefore, took the temperature of ebullition for each liquid as the proper origin, instead of a common temperature, such as that of melting ice, which must correspond to dissimilar molecular states in various fluids. At their boiling points, the repulsive force of the molecules should be the same; it is natural to suppose, therefore, that the comparative variations of dilatation would be more regular, if reckoned from such a physical point for each. The idea was ingenious, and it led to the discovery of a remarkable coincidence between the dilatation of alcohol and that of the sulphuret of carbon, but not of any general physical law.

85. The apparatus for each liquid consisted of a thermometer tube of carefully determined capacity, filled with a quantity of the fluid, of which the volume was assumed to be 1000 at its boiling point, and the contractions were estimated proportionally at inferior temperatures. For alcohol, of which the density was found by experiment to be 0 79235 at 17°.88 cent., and 0.73869 at 78.°41, or its boiling point, that of water at its maximum density being unity; and for water, the density of which at 100° cent, its boiling point, was 0 96064, the following table gives the observed contractions:

*Ann. de Chim. et de Phys. t. 2. p. 130.

TABLE XX.

| Water. | | | | Alcohol. | | | |
|---|---|---|---|---|---|---|---|
| Temperature. | Contraction. | Temperature. | Contraction. | Temperature. | Contraction. | Temperature. | Contraction. |
| 0.0 | 0.00 | 61.5 | 32.94 | 0.0 | 0.00 | 47.9 | 53.81 |
| 3.6 | 2.44 | 67.4 | 34.76 | 4.4 | 4.90 | 51.9 | 57.92 |
| 8.0 | 5.40 | 72.2 | 36.07 | 5.5 | 6.06 | 56.7 | 62.74 |
| 9.2 | 6.13 | 76.1 | 36.94 | 6.7 | 7.59 | 61.2 | 67.15 |
| 14.3 | 10.13 | 78.7 | 37.45 | 11.6 | 13.25 | 62.9 | 68.88 |
| 21.0 | 13.68 | 80.2 | 37.74 | 15.2 | 17.82 | 63.5 | 69.38 |
| 26.6 | 17.00 | 80.4 | 37.85 | 19.8 | 23.13 | 65.5 | 71.16 |
| 33.1 | 20.53 | 84.5 | 38.25 | 23.6 | 27.52 | 67.3 | 72.97 |
| 39.9 | 24.06 | 86.0 | 38.52 | 26.8 | 31.15 | 70.7 | 76.10 |
| 46.2 | 26.95 | .... | ..... | 31.8 | 36.79 | 72.5 | 77.85 |
| 51.4 | 29.14 | .... | ..... | 34.8 | 40.05 | 73.8 | 79.03 |
| 56.4 | 31.16 | .... | ..... | 40.8 | 46.57 | .... | ..... |

No correction was made in these results for the contraction of the glass, for there is another counteracting variation, dependent upon the vapour which fills the space in the tube above the liquid, and the film which coats its inner wall, the amount of which cannot be accurately determined.

86. To render the law of dilatation more evident for each of these liquids, M. Despretz, at the request of M. Gay Lussac, computed from the data of the preceding table, by means of Biot's formula,

$$c = at + bt^2 + ct^3,$$

another table, hereto annexed, in which the temperature decreases by regular intervals of five degrees, commencing at the point of ebullition, as the zero or origin.

TABLE XXI.

| Water. | | | | Alcohol. | | | |
|---|---|---|---|---|---|---|---|
| Temperature. | Contraction. | Temperature. | Contraction. | Temperature. | Contraction. | Temperature. | Contraction. |
| ° | | ° | | ° | | ° | |
| 0 | 0.00 | 40 | 24.20 | 0 | 0.00 | 40 | 45.66 |
| 5 | 3.35 | 45 | 26.52 | 5 | 5.56 | 45 | 51.11 |
| 10 | 6.65 | 50 | 28.61 | 10 | 11.24 | 50 | 56.37 |
| 15 | 9.89 | 55 | 30.43 | 15 | 17.00 | 55 | 61.43 |
| 20 | 13.02 | 60 | 31.96 | 20 | 23.41 | 60 | 66.23 |
| 25 | 16.06 | 65 | 33.19 | 25 | 28.60 | 65 | 70.75 |
| 30 | 18.95 | 70 | 34.09 | 30 | 34.37 | 70 | 74.93 |
| 35 | 21.67 | 75 | 34.63 | 35 | 40.05 | 75 | 78.75 |

87. I have already given quite a full account of the *centesimal alcoholometer* of M. Gay Lussac, and the simple idea upon which it is based, in my former report,* to which I, therefore, respectfully refer. In that paper I made the assertion, which I have repeated in this, that Gay Lussac has not published the data for the construction either of his tables or the instrument to which they belong. To justify this *negative* statement of matters of fact, I should here give my authority for so doing.

M. Dumas, who must have had full opportunity of ascertaining, says:† "The experiments of Gay Lussac were made with extreme care; but he has published only the results relative to the use of his centisimal alcoholometer, without giving the densities employed for its construction."

88. In the absence, therefore, of direct and authentic information from Gay Lussac himself, we must either depend upon the testimony of others, which he has at least allowed to go without contradiction, and probably authorized, or reverse the calculations by which the numbers of his tables were computed from the specific gravities given by experiment, and thus seek to obtain the latter. This second method would be perfect, if the numbers in the tables were exact, which cannot, however be assumed; for it is very probable that, like those of the similar tables of Tralles, (see § 67,) they are not in all cases accurate to so small a quantity as the tenth of a per cent.

89. In his excellent treatise‡ on chemistry, Berzelius says: "More

* Senate Doc. No. 165, 28th Cong., 2d Sess., p. 68 and p. 76.

† "Les expériences de M. Gay Lussac ont été faites avec un soin extrême, mais il n'a publié que les résultats rélatifs à l'emploi de son alcoomètre centésimal, sans donner les densités d'où il est parti pour le construire."—Traité de Chim. Appliq. aux Arts, t. V., p. 483.

‡ First French edition, t VI., p. 488.

recently Gay Lussac has made tables to be used for assaying and mixing spirituous liquors. These tables, made for the normal temperature 15° cent., depend upon the following densities of anhydrous alcohol, and of its mixtures with water; which densities are referred to that of water at 15°, and not to that which it would have at its maximum density."

TABLE XXII.

| Per cent. of alcohol. | Specific gravity. | Per cent. of alcohol. | Specific gravity. |
|---|---|---|---|
| 100 | 0.7947 | 60 | 0.9141 |
| 95 | 0.8168 | 55 | 0.9248 |
| 90 | 0.8346 | 50 | 0.9348 |
| 85 | 0.8502 | 45 | 0.9440 |
| 80 | 0.8645 | 40 | 0.9523 |
| 75 | 0.8779 | 35 | 0.9595 |
| 70 | 0.8907 | 30 | 0.9656 |
| 65 | 0.9027 | 0 | 1.0000 |

"These numbers appear," says Berzelius, "to be based upon experiments which Gay Lussac has not published; for, although they differ essentially from those of Tralles, only by reason of the circumstance that one has compared the weight of alcohol to that of water as unity at the temperature of 15°, while the other has taken 0.9991 as the density of water at that temperature, yet when we reduce the numbers of Tralles (See TABLE VII.), for one degree of Fahrenheit, or 59°, and then divide them by 0.9991, differences will be observed. It is thus found that the density of the anhydrous alcohol of Tralles is 0.7951. The differences in the specific gravities of the mixtures become still smaller, and in the last third of the series they disappear entirely. Hence, it is evident that Gay Lussac determined the density of alcohol with greater exactness, and from the discrepancies which are found when his numbers are compared by calculation with those of Tralles, it also follows that Gay Lussac corrected the densities of the mixtures. In every instance, the difference is, however, so small that, for practical purposes, it may be disregarded."

90. That Berzelius must have had good authority for all that he has thus said, results not only from his almost proverbial accuracy in matters of science, but also from the responsibility which he assumed in his connexion with the action of the Swedish government, of which he thus speaks:

"Until the close of the year 1827, the method of examination of Wilcke was used in Sweden. But in 1828, the Swedish government, at the recommendation of the Academy of Sciences, adopted a much more convenient and certain method, which had already been established in Prussia and in France." * * * * * * "As the temperature 15° cent. used in France, is nearly the mean temperature at which spirituous liquors are guaged and inspected, and

as, by its adoption, the work of Gay Lussac done for France, which is the most complete and the best adapted to general use of any yet performed, would become applicable for Sweden, the Swedish government fixed the temperature at 15° cent, to which the volumes are to be reduced in all measurements of ardent spirits." * * * * "The centesimal alcoholmeter, constructed according to the data of Gay Lussac, is now adopted in Sweden, and by law the tables which he has prepared are to be employed in the examination of spirits."

91. In the article *Alcohol*, of the *Dictionnaire de Technologie*,* M. Pelouze gives the same table (TABLE XXII.), as that of M. Gay Lussac, and adds: "it is upon these densities that Gay Lussac based the construction of his tables for the mixing (*mouillage*) of spirituous liquids."

Where MM. Pelouze and Berzelius got this table from, they only know; I have been unable to find it, or any reference except to Berzelius for it;† upon their authority I however adopt it in the calculations I have made for the comparison of the results of Gay Lussac with those of Tralles and others. (See sections 107 and 108.)

92. The tables of M. Gay Lussac, published in the form of a small book entitled "*Instruction pour l'usage de l'Alcoometre centesimal, et des tables qui l'accompagnent; par M. Gay Lussac, &c.,*" are four in number. Of these, the last is simply a multiplication table for all numbers between 1 and 1000, to render more easy and certain the multiplications and divisions which may have to be made by unskillful persons in the use of the alcoholometer. The third table refers to the mixing of liquors of given strength, for the purpose of producing one of any required per cent. Such a table, though indispensable to dealers and distillers, can have no application in the revenue, except in relation to questions which may arise from attempts to evade laws unskillfully framed; for it would furnish the information required by a dealer, who would wish to import a liquor so reduced in quality that it would pay duty as of inferior strength, but be saleable as of higher proof. The first and second tables are, however, those which relate to the subject of determining the proper duty to be levied, and which, therefore, require particular notice here. For revenue purposes, only one of these is necessary, that already alluded to in section 13, which gives the *richness* or *value* of a liquor, of which the number of gallons and strength are determined at any indicated temperature. This table, the second of Gay Lussac, is identical in its nature and object with TABLES XIII. and XIV., constructed by Tralles, and must have been based upon data similar to those contained in TABLE X.; it differs from TABLES XIII. and XIV. in its arrangement, which is im-

* Abrégé du Grande Dict. de Technol. t. i., p. 123.

† "Gay Lussac selbst scheint von den Fundamental Bestimmungen nach welchen er sein Alkoholometer construirt hat, nichts bekannt gemacht zu haben. In dess giebt Berzelius in seinem Lehrbuch hierüber folgende Tafel." Poggendorff in the H. w. buch d. chem. vol. 1, p. 294.

proved by causing the *indication* and *real strength* to change places, so that the former becomes the argument instead of the latter; and it is computed to every single per cent., or degree of the alcoholometer. In this report, designed to furnish fundamental data rather than practical instruction, it would be inappropriate to embody such a table. The following extract from it may, however, serve as a specimen of the whole; and it will, probably, render what has been said more clear to some persons. It has been selected at random from the midst of the table.

| Temp. | 61 c. | 62 c. | 63 c. | 64 c. | 65 c. |
|---|---|---|---|---|---|
| 0° | 66.8 | 67.8 | 68.8 | 69.8 | 70.8 |
| 1 | 66.5 | 67.5 | 68.5 | 69.4 | 70.4 |
| 2 | 66.1 | 67.1 | 68.1 | 69.1 | 70.1 |
| 3 | 65.6 | 66.6 | 67.6 | 68.6 | 69.6 |
| 4 | 65.3 | 66.3 | 67.3 | 68.3 | 69.3 |
| 5 | 64.9 | 65.9 | 66.9 | 67.9 | 68.9 |
| 6 | 64.5 | 65.5 | 66.5 | 67.5 | 68.5 |
| 7 | 64.1 | 65.1 | 66.1 | 67.1 | 68.1 |
| 8 | 63.8 | 64.8 | 65.8 | 66.8 | 67.7 |

The figures, 61c, 62c, etc., denote the indications of the instrument; the small letter *c* being an abbreviation of the word *centimes*, or hundredths.

93. The remaining table of Gay Lussac, the first in order of the series as published by him, may be considered an ingenious combination of the TABLES VIII. and XII. of Tralles, computed for every single per cent., and substituting in place of the densities of TABLE VIII., their corresponding volumes. The following is a specimen of it:

| Temp. | 91 c. | 92 c. | 93 c. | 94 c. | 95 c. |
|---|---|---|---|---|---|
| 15° | 91<br>1000 | 92<br>1000 | 93<br>1000 | 94<br>1000 | 95<br>1000 |
| 16 | 90.8<br>999 | 91.8<br>999 | 92.8<br>999 | 93.8<br>999 | 94.8<br>999 |
| 17 | 90.5<br>998 | 91.5<br>998 | 92.6<br>998 | 93.6<br>998 | 94.6<br>998 |
| 18 | 90.2<br>997 | 91.3<br>997 | 92.3<br>997 | 93.3<br>997 | 94.3<br>997 |
| 19 | 90<br>996 | 91.1<br>996 | 92.1<br>996 | 93.1<br>996 | 94.1<br>996 |
| 20 | 89.7<br>995 | 90.8<br>995 | 91.8<br>995 | 92.9<br>995 | 93.9<br>995 |
| 21 | 89.5<br>994 | 90.5<br>994 | 91.6<br>994 | 92.6<br>994 | 93.7<br>994 |
| 22 | 89.2<br>993 | 90.2<br>993 | 91.3<br>993 | 92.4<br>993 | 93.4<br>993 |

The first horizontal column contains the observed indications of the hydrometer; the first vertical column, the observed temperature; and the two numbers in any of the spaces of the table denote, respectively, the per cent. and the volume reduced to 15° C. Thus, for example, opposite to the temperature 20° and beneath the indication 92c, we have the two numbers, 90.8 and 995; of which the first 90.8 is the true per cent. by volume or strength of the liquor at 15°, and 995 the number of gallons at that temperature, which would expand to 1000 if heated to 20° cent. The product of these numbers $995 \times 90.8 = 90.346$ is the *richness* or true per cent. of alcohol in such a liquor, which would be obtained if both the strength and number of gallons were ascertained at 15° instead of 20°, centigrade. It is in this manner that Gay Lussac computed his table of *richness*, which dispenses with calculations, and which has been discussed in the preceding section.

94. *Experiments of Gouvernain.*—To render this report complete, with reference to researches made in France, a brief account of the experiments of Gouvernain should be given, although they are of inferior accuracy. The results were published in 1825, at Dijon, in pamphlet form;* and the mixtures were made by volume, at the indicated temperatures both for the alcohol and water. The following table contains the specific gravities obtained; water at 10° Reaum., being 1000.

| Per ct. of alcohol. | 0°. | 5°. | 10°. | 15°. | 20°. |
|---|---|---|---|---|---|
| 10 | 989.50 | 988.25 | 987.00 | 985.75 | 984.50 |
| 20 | 979.50 | 978.00 | 976.50 | 975.00 | 973.50 |
| 30 | 971.75 | 969.25 | 966.75 | 964.25 | 961.75 |
| 40 | 960.00 | 956.50 | 953.00 | 949.50 | 946.00 |
| 50 | 943.00 | 939.00 | 935.00 | 931.00 | 927.00 |
| 60 | 924.00 | 919.00 | 914.00 | 909.00 | 904.00 |
| 70 | 900.30 | 895.15 | 890.00 | 884.85 | 879.70 |
| 80 | 874.40 | 869.20 | 864.00 | 858.80 | 853.60 |
| 90 | 846.50 | 841.25 | 836.00 | 830.75 | 825.50 |
| 100 | 810.60 | 805.30 | 800.00 | 794.7 | 789.40 |

RECENT EXPERIMENTS IN ENGLAND.

95. *By Mr. Fownes.*—In the Philosophical Transactions of the Royal Society for 1847, page 249, there is a paper by Mr. Fownes, "on the value in absolute alcohol of spirits of different specific gravities," giving the results of a series of experiments arranged in tabular form.

"The table," says Mr. Fownes, "was formed synthetically; absolute alcohol and distilled water were weighed out in the required proportions, mixed in small well stopped bottles and well shaken to-

* Ferrussac Bulletin univ. des sciences mathematiques, t. vii. p. 147.

gether. After standing three or four days the mixtures were brought to the temperature of 60° Fahrenheit exactly, and their specific gravities determined with great care. After the lapse of two or three days more, this last named operation was repeated, but in no case was it observed that any further contraction had occurred. Neither was the specific gravity of a mixture containing nearly equal parts of alcohol and water, which had been so examined, changed by being inclosed in a strong accurately stoppered bottle and heated for some time to a temperature above its boiling point."

"In this manner each number in the annexed table was obtained by experiment. When completed, this table was examined by various methods to test its accuracy, but no error of sufficient magnitude to limit its usefulness was detected."

96. "The absolute alcohol employed in these experiments was prepared in the following manner: the strongest rectified spirits was agitated with half its weight of carbonate of potash, deprived of water of crystalization, and then left in contact with the salt some days. It was then decanted upon half its weight of powdered quick lime, made from black marble, contained in a metal still, which could be perfectly closed. The mixture of spirit and lime was retained in a warm situation for a week or thereabouts, and then distilled by means of a water bath. By this treatment the specific gravity of the alcohol was generally reduced to 0.796, or even below, and by a repetition of the process of digestion with powdered lime and re-distillation, the last traces of water were removed. In this manner, without difficulty, the very considerable quantity of absolute alcohol required for the experiments was procured."

"Absolute alcohol thus obtained has the specific gravity 0.7938 at 60° Fahrenheit; it is extremely expansible by heat, which renders the determination of its exact specific gravity difficult and troublesome, when the temperature of the room is either above or below 60° Fahrenheit. The same remark applies to the mixtures of alcohol and water extending over more than half the table, the most minute precaution regarding temperature being necessary to avoid serious errors. In a glass retort containing pieces of copper foil absolute alcohol boils at 177° Fahrenheit, the barometer being at 29.75 inches. Lastly, when analyzed by combustion with oxide of copper, it yields numbers representing the proportions of carbon and hydrogen present so closely agreeing with those required by theory, as to leave no doubt of its purity and freedom from all admixture."

TABLE XXIII.

*Showing the proportion by weight of real or absolute alcohol contained in* 100 *parts of spirits of different specific gravities, at the temperature of* 60° *Fahrenheit.*

| Per cent. | Sp. grav. | Per cent. | Sp. grav. | Per cent. | Sp. grav. | Per cent. | Sp. grav. |
|---|---|---|---|---|---|---|---|
| 0.5 | 9991 | 26 | 9638 | 52 | 9135 | 78 | 8533 |
| 2 | 9965 | 28 | 9609 | 54 | 9090 | 80 | 8483 |
| 4 | 9930 | 30 | 9578 | 56 | 9047 | 82 | 8434 |
| 6 | 9898 | 32 | 9544 | 58 | 9001 | 84 | 8382 |
| 8 | 9869 | 34 | 9511 | 60 | 8956 | 86 | 8331 |
| 10 | 9841 | 36 | 9470 | 62 | 8908 | 88 | 8279 |
| 12 | 9815 | 38 | 9434 | 64 | 8863 | 90 | 8228 |
| 14 | 9789 | 40 | 9396 | 66 | 8816 | 92 | 8172 |
| 16 | 9766 | 42 | 9356 | 68 | 8769 | 94 | 8118 |
| 18 | 9741 | 44 | 9314 | 70 | 8721 | 96 | 8061 |
| 20 | 9716 | 46 | 9270 | 72 | 8672 | 98 | 8001 |
| 22 | 9691 | 48 | 9228 | 74 | 8625 | 100 | 7938 |
| 24 | 9665 | 50 | 9184 | 76 | 8581 | | |

97. It should be observed that Mr. Fownes gives us no information with reference to the accuracy of his weighings, and the reductions which he performed to obtain the data of his table from the observed results. We are thus left to conjecture whether any correction was applied for loss of weight by atmospheric buoyancy.

A still greater oversight, not uncommon with English chemists, has been committed by him in omitting to state the density which he assumes as unity; whether the maximum density of water, or that which it has at 60° Fahrenheit, or any other arbitrary temperature. Also, while he directs attention to the "extreme expansibility by heat of alcoholic liquids, and the minute precautions regarding temperature necessary to avoid serious errors," he tells us nothing of the sensibility and accuracy of his thermometer, or of the manner in which he succeeded in taking the specific gravities of his mixtures at "the temperature of 60° Fahrenheit, *exactly*." These omissions greatly impair the value of his paper; for, however skillful a chemist may be, he cannot reasonably substitute the authority of his reputation for the faithful and detailed narration of observed facts, without detracting from the merit of his work.

98. *Researches of Mr. Drinkwater.*—These are still more recent than those of Mr. Fownes, and are published in the London and Edinburgh Philosophical Magazine, for February, 1848.

Mr. Drinkwater says of his experiments, that they "were undertaken, principally, with a view to determine the relative proportions of anhydrous alcohol and water in revenue proof spirit." Certainly, we need no further commentary on the uncertainty and arbitrary nature of the British system than that which is furnished by the fact, that at the present day one of the chemists of that country should find it necessary to perform a laborious series

of experiments to determine the composition of "proof spirit," which he himself informs us is defined by act of parliament, 58 George III., c. 28, to be "such as shall, at the temperature of fifty-one degrees, by Fahrenheit's thermometer, weigh exactly twelve thirteenth parts of an equal measure of distilled water;" a definition which, as Mr. Drinkwater says, is incomplete, because the temperature of the water is not expressly stated, but may be inferred to be fifty-one degrees, or the same as that of the spirit. That this "proof spirit" is perfectly arbitrary is evident. That out of the country where it is fixed by law, and adhered to by force of technical routine and rigid custom, it can have no interest, and still less any value, to recommend its adoption, will be sufficient reason for omitting all mention here of what Mr. Drinkwater has done and said with reference to it, except the final result to which he was led, that British "revenue proof spirit" is composed of 49.24 per cent. by weight of pure alcohol, and 50.76 per cent. of water, and has a specific gravity equal to 0.91984 at 60° Fahrenheit; that of water at the same temperature being unity.

99. To ascertain by synthesis the above result, Mr. Drinkwater was obliged to prepare absolute or pure alcohol, and for that purpose made the following experiments:

"Carbonate of potash was exposed to a red heat to deprive it of water, and when sufficiently cool was pulverized and added to ordinary alcohol of specific gravity 0.850 at 60° F., till it ceased to dissolve any more; the whole was then allowed to digest twenty-four hours, being frequently agitated, and the alcohol was carefully poured off."

"As much freshly burned quicklime as was considered sufficient when powdered to absorb the whole of the alcohol was introduced into a retort, and the alcohol added to it. After digesting forty-eight hours, it was slowly distilled in a water bath at the temperature of about 180° Fahr."

"The alcohol thus obtained was carefully redistilled, and its specific gravity at 60° Fahr. was found in two experiments to be .7946 and .7947; agreeing very nearly with the determination of Rudberg, which has been adopted by Gay Lussac and others, viz: .7947 at 59° F."*

"It may be proper to state, that the specific gravity was taken with a stoppered bottle, which was always counterpoised by another empty bottle of the same glass and form, placed in the opposite pan of the balance; the capacity of the weighing bottle, at 60° F., was exactly 1000.01 grains of distilled water; and it was found on trial that this bottle could be repeatedly filled with the same liquid with no greater variation than one or two hundredths of a grain."

"The temperature of the room in which these experiments were

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* This assertion is in error. (See section 141.)

made, was always brought to 60° F.; and the thermometer used was a standard instrument by Newman, and extremely sensitive, (being graduated to one-tenth of a degree); on being plunged into the weighing bottle filled with alcohol it displaced about 4½ grains of that fluid; this portion was replaced from the stock quantity (brought at the time to the proper temperature) by means of a pipette."

"With a view, however, to discover whether it were possible by means of lime to abstract any more water from the alcohol, the retort was again filled with fresh-burned and pulverized quicklime and the same alcohol mixed with it; the mixture was then allowed to digest a whole week at the ordinary temperature of the laboratory, about 60° F. After this time the alcohol was distilled off as before, but was redistilled very slowly, at first at the rate of about one drop in ten seconds, (heat of water bath, 165° F.,) this was continued till about one-twentieth of the whole had distilled over, the object being to allow any minute quantity of water which the alcohol might still retain to evaporate or diffuse itself into the atmosphere of absolute alcohol above it; the redistillation was then continued rapidly, the heat of the bath being increased to 180° F. till about one-twentieth more had passed over; the receiver was then changed and the remaining part slowly distilled off."

"The specific gravity of this alcohol taken twice was .7944 at 60° F. As a further test of its purity, it was divided into two equal parts; one part was again digested on quicklime, and the other on sulphate of copper deprived of water by heat, the method of operation being as follows:"

"1. Some lumps of fresh-burned quicklime were heated to a red heat, and in that state quickly pulverized and introduced into the tin boiler of a small still, which was partly immersed in water to prevent the melting of the solder."

"This vessel was completely filled with quicklime, and was kept corked till sufficiently cool, when the alcohol was added, but it being comparatively small in quantity the lime appeared perfectly dry; the vessel was then securely corked."

2. "A quantity of sulphate of copper was exposed to a red heat till completely deprived of water; it was then quickly pulverized and introduced into a small tin boiler, and when cold the alcohol (which was insufficient to cover it) was added, and the vessel closely corked."

"These vessels with their contents were kept at the ordinary temperature of the laboratory, about (60° Fahrenheit,) for four days; they were then partly immersed in a water-bath, and kept at a temperature of about 150° Fahrenheit for forty-eight hours, after which the alcohol was distilled and re-distilled with all the precautions before mentioned; the temperature of the water-bath on the re-distillation never exceeded 172° Fahrenheit, and the first tenth part was put aside in each case as possibly impure."

"The specific gravities of the alcohol thus obtained were as under:—

| | Alcohol distilled from desiccated sulphate of copper. | Alcohol distilled from quicklime. |
|---|---|---|
| I. | .79470 | .79409 |
| II. | .79472 | .79412 |

"From these experiments it would appear that sulphate of copper, when deprived of water, is not so effective as quicklime in removing the last traces of water from alcohol."

"It was observed, however, that in general the specific gravity of the alcohol gradually increased, probably from its hygrometric property, by which it absorbed a minute quantity of moisture from the air on being transferred from one bottle to another; and thinking, consequently, that a small quantity of moisture might have been abstracted from the atmosphere during the distillation, (which was conducted in the usual way,) and the specific gravity thus slightly increased, I considered it desirable to make another experiment, in which this source of error should be guarded against, by conducting the distillation as much as possible out of contact with the external air, and proceeded as follows:"

"The different portions of alcohol before obtained were mixed together, when the specific gravity was found to be .7947; this alcohol was again digested at a temperature of about 150° Fahrenheit for fourteen days with quicklime, previously heated to redness, as in the former experiment; it was then slowly distilled out of contact with the external atmosphere by means of a tube which passed from the condenser through a cork into the bottle in which it was to remain, (the temperature of the water-bath was 175° Fahrenheit,) and the first tenth part was put aside as possibly containing a minute quantity of water; the remainder was then distilled off at 178° to 180° Fahrenheit."

"This alcohol was quickly transferred to a dry retort and redistilled in a similar way, (heat of water-bath 172° Fahrenheit;) the first tenth part was put aside, and the remainder kept as being pure anhydrous alcohol, or as free from water as it is possible to obtain it by this process. The specific gravity was taken the next day with all the precautions before mentioned, the alcohol being also kept, during the time of transference, as much as possible out of contact with humid air, when the results of four trials were as follows:"

Temperature of the room, 60° F.; Barometer, 29.810.

| | |
|---|---|
| I. | .793836 |
| II. | .793806 |
| III. | .793798 |
| IV. | .793804 |
| Mean | .793811 |

"A portion of this alcohol was subsequently digested with quicklime for three months; it was then distilled, and its specific

gravity was found to be exactly the same as before. We may, therefore, conclude with considerable certainty that the number 0.79381 expresses the specific gravity of absolute alcohol at 60° Fahrenheit, within a very close degree of approximation."

100. In making his mixtures, Mr. Drinkwater used the following process: "Two light flasks were procured, capable of containing each 2,200 grains of water. The alcohol and water were weighed separately in these flasks with the greatest care; after which, the flasks were joined without mixing the liquids—the neck of one being ground into the neck of the other for that purpose. The liquids were then thoroughly mixed by transferring them alternately from one flask to the other. The flasks were disconnected when the mixed contents became cool, which were then transferred to a clean and dry well-stoppered bottle, and further secured by tying a piece of caoutchouc over the stopper."

"It may also be proper to mention that, when placed in the balance, these flasks were always counterpoised by other empty flasks of the same material, and of very nearly equal size and shape; and to prevent loss from evaporation, a ground glass cap was placed over the mouth of each flask as soon as the exact weight was obtained. The errors of observation could not, I believe, in any case exceed one hundredth of a grain, as the balance used in these experiments was one of Robinson's best instruments, which was previously adjusted by Newman expressly for the purpose; it was turned, with its greatest load, by less than one hundredth of a grain."

101. Having found the table of Lowitz, which is frequently given in English chemical works, incorrect, Mr. Drinkwater "considered it desirable to make a few mixtures of pure alcohol and water, from which to calculate a more correct table for estimating the quantity of alcohol in mixtures containing not more than ten per cent. of that liquid."

"Eleven mixtures were, therefore, made, containing exactly ½, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 per cent. by weight of absolute alcohol. These mixtures were made in the same apparatus, and with all the precautions described in the former experiments. They were allowed to stand at least twenty-four hours, with occasional agitation, before the specific gravities were taken; and several of them were taken again after a period of forty-eight and seventy-two hours, without any sensible variation. The particulars are set forth in the following table:

TABLE XXIV.

| Number of mixtures. | When the mixtures were made. | | | | | When the specific gravities were taken. | | |
|---|---|---|---|---|---|---|---|---|
| | Alcohol and water mixed. | | Quantity of alcohol.—Per ct. by weight. | Temperature of room. | Height of barometer. | Specific gravity of mixture at 60° F. | Temperature of room. | Height of barometer. |
| | Alcohol. | Water. | | | | | | |
| | *Grs.* | *Grs.* | | | | | | |
| 1 | 5.5 + | 1094.5 | 0.5 | 60° | 29.700 | .99905 | 60F. | 29.690 |
| 2 | 11.0 + | 1089.0 | 1.0 | 60 | 29.700 | .99813 | 60 | 29.690 |
| 3 | 22.0 + | 1078.0 | 2.0 | 60 | 29.690 | .99629 | 60 | 29.500 |
| 4 | 33.0 + | 1067.0 | 3.0 | 60 | 29.718 | .99454 | 60 | 29.610 |
| 5 | 44.0 + | 1056.0 | 4.0 | 60 | 29.690 | .99283 | 60 | 29.500 |
| 6 | 55.0 + | 1045.0 | 5.0 | 60 | 29.718 | .99121 | 60 | 29.610 |
| 7 | 66.0 + | 1034.0 | 6.0 | 60 | 29.742 | .98963 | 60 | 29.644 |
| 8 | 77.0 + | 1023.0 | 7.0 | 60 | 29.742 | .98813 | 60 | 29.644 |
| 9 | 88.0 + | 1012.0 | 8.0 | 60 | 29.670 | .98668 | 60 | 29.800 |
| 10 | 99.0 + | 1001.0 | 9.0 | 60 | 29.670 | .98527 | 60 | 29.800 |
| 11 | 110.0 + | 990.0 | 10.0 | 60 | 29.800 | .98389 | 60 | 29.566 |

From the above data the following table has been calculated:

## TABLE XXV.

*Table of the quantity of absolute alcohol by weight contained in mixtures of alcohol and water of the following specific gravities:*

| Specific gravity at 60° F. | Alcohol.—Per ct. by weight. | Specific gravity at 60° F. | Alcohol.—Per ct. by weight. | Specific gravity at 60° F. | Alcohol.—Per ct. by weight. | Specific gravity at 60° F. | Alcohol.—Per ct. by weight. | Specific gravity at 60° F. | Alcohol.—Per ct. by weight. |
|---|---|---|---|---|---|---|---|---|---|
| 1.0000 | 0.00 | .9967 | 1.78 | .9934 | 3.67 | .9901 | 5.70 | .9869 | 7.85 |
| .9999 | 0.05 | .9966 | 1.83 | .9933 | 3.73 | .9900 | 5.77 | .9868 | 7.92 |
| .9998 | 0.11 | .9965 | 1.89 | .9932 | 3.78 | .9899 | 5.83 | .9867 | 7.99 |
| .9997 | 0.16 | .9964 | 1.94 | .9931 | 3.84 | .9898 | 5.89 | .9866 | 8.06 |
| .9996 | 0.21 | .9963 | 1.99 | .9930 | 3.90 | .9897 | 5.96 | .9865 | 8.13 |
| .9995 | 0.26 | .9962 | 2.05 | .9929 | 3.96 | .9896 | 6.02 | .9864 | 8.20 |
| .9994 | 0.32 | .9961 | 2.11 | .9928 | 4.02 | .9895 | 6.09 | .9863 | 8.27 |
| .9993 | 0.37 | .9960 | 2.17 | .9927 | 4.08 | .9894 | 6.15 | .9862 | 8.34 |
| .9992 | 0.42 | .9959 | 2.22 | .9926 | 4.14 | .9893 | 6.22 | .9861 | 8.41 |
| .9991 | 0.47 | .9958 | 2.28 | .9925 | 4.20 | .9892 | 6.29 | .9860 | 8.48 |
| .9990 | 0.53 | .9957 | 2.34 | .9924 | 4.27 | .9891 | 6.35 | .9859 | 8.55 |
| .9989 | 0.58 | .9956 | 2.39 | .9923 | 4.33 | .9890 | 6.42 | .9858 | 8.62 |
| .9988 | 0.64 | .9955 | 2.45 | .9922 | 4.39 | .9889 | 6.49 | .9857 | 8 70 |
| .9987 | 0.69 | .9954 | 2.51 | .9921 | 4.45 | .9888 | 6.55 | .9856 | 8.77 |
| .9986 | 0.74 | .9953 | 2.57 | .9920 | 4.51 | .9887 | 6.62 | .9855 | 8.84 |
| .9985 | 0.80 | .9952 | 2.62 | .9919 | 4.57 | .9886 | 6.69 | .9854 | 8.91 |
| .9984 | 0.85 | .9951 | 2.68 | .9918 | 4.64 | .9885 | 6.75 | .9853 | 8.98 |
| .9983 | 0.91 | .9950 | 2.74 | .9917 | 4.70 | .9884 | 6.82 | .9852 | 9.05 |
| .9982 | 0.96 | .9949 | 2.79 | .9916 | 4.76 | .9883 | 6.89 | .9851 | 9.12 |
| .9981 | 1.02 | .9948 | 2.85 | .9915 | 4.82 | .9882 | 6.95 | .9850 | 9.20 |
| .9980 | 1.07 | .9947 | 2.91 | .9914 | 4.88 | .9881 | 7.02 | .9849 | 9.27 |
| .9979 | 1.12 | .9946 | 2.97 | .9913 | 4.94 | .9880 | 7.09 | .9848 | 9.34 |
| .9978 | 1.18 | .9945 | 3.02 | .9912 | 5.01 | .9879 | 7.16 | .9847 | 9.41 |
| .9977 | 1.23 | .9944 | 3.08 | .9911 | 5.07 | .9878 | 7.23 | .9846 | 9.49 |
| .9976 | 1.29 | .9943 | 3.14 | .9910 | 5.13 | .9877 | 7.30 | .9845 | 9.56 |
| .9975 | 1.34 | .9942 | 3.20 | .9909 | 5.20 | .9876 | 7.37 | .9844 | 9.63 |
| .9974 | 1.40 | .9941 | 3.26 | .9908 | 5.26 | .9875 | 7.43 | .9843 | 9.70 |
| .9973 | 1.45 | .9940 | 3.32 | .9907 | 5.32 | .9874 | 7.50 | .9842 | 9.78 |
| .9972 | 1.51 | .9939 | 3.37 | .9906 | 5.39 | .9873 | 7.57 | .9841 | 9.85 |
| .9971 | 1.56 | .9938 | 3.43 | .9905 | 5.45 | .9872 | 7.64 | .9840 | 9.92 |
| .9970 | 1.61 | .9937 | 3.49 | .9904 | 5.51 | .9871 | 7.71 | .9839 | 9.99 |
| .9969 | 1.67 | .9936 | 3.55 | .9903 | 5.58 | .9870 | 7.78 | .9838 | 10.07 |
| .9968 | 1.73 | .9935 | 3.61 | .9902 | 5.64 | | | | |

102. I have now given a very full and complete account of all the researches with reference to the specific gravities and corresponding strengths of alcoholic liquors, of which I possess any knowledge. Although I have made diligent search for such information, it is probable that similar experiments may have been performed, which have escaped my notice, but which may hereafter become known to me; if so, and they should contain anything of importance, I will communicate it in a future or supplementary report.

I shall next endeavor to show, by comparing the preceding results, to what extent they confirm or conflict with each other; in order that the facts which they establish by their collective evidence may be rendered manifest; and that any series of data which may be adopted by our government may readily be seen to be both just and true, if in accordance with such cumulative testimony of different and skilful observers.

*Verification of the preceding results, by comparison with each other.*

103. In explanation of the following table of comparison between the results of the last series of experiments of Messrs. Gilpin and Blagden, (see TABLE IV.,) and those of M. Delezennes, (see TABLE XIX.,) it should be stated that the following calculations were made: the equivalent per cents. by weight for the mixtures of Messrs. Gilpin and Blagden were obtained, as well as that for their standard alcohol of the specific gravity 0.825 at 60°, the alcohol of Delezennes being taken as 100 per cent., or absolute; this gave a series of mixed numbers integral and fractional, as those for the first column of Gilpin's work. The corresponding specific gravities, taken from TABLE IV., were then reduced to the scale of water unity at 0°c. or 32° Fahrenheit, instead of 60° Fahrenheit, employing Gilpin's data for the reduction, which were arranged in a second vertical column. In this manner a subsidiary table was formed, from which the specific gravities, given as those of Gilpin, were obtained by means of a rigid formula of interpolation, account being taken of the second differences.

## TABLE XXVI.

| Per cent. of alcohol by weight. | Specific gravity at 0° cent. | | | Specific gravity at 18° cent. | | | Specific gravity at 36° cent. | | | Difference of per cent. by volume corresponding to differences of sp. gravity between G and D. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gilpin. | Delezennes. | Diff. | Gilpin. | Delezennes. | Diff. | Gilpin. | Delezennes. | Diff. | 0° cent. | 18° cent. | 36° cent. |
| 0 | 1.00000 | 1.00000 | .... | ..... | 99855 | .... | ..... | 99351 | .... | .... | .... | .... |
| 5 | 99173 | 99130 | +43 | 99023 | 98983 | +40 | ..... | 98520 | .... | 0.30 | 0.27 | .... |
| 10 | 98530 | 98504 | 26 | 98297 | 98261 | 36 | ..... | 97684 | .... | .20 | .30 | .... |
| 15 | 98020 | 98007 | 13 | 97622 | 97587 | 35 | ..... | 96853 | .... | .15 | .35 | .... |
| 20 | 97592 | 97596 | —04 | 96992 | 96974 | 18 | ..... | 96084 | .... | .04 | .18 | .... |
| 25 | 97147 | 97145 | +02 | 96327 | 96312 | 15 | ..... | 95254 | .... | .02 | .15 | .... |
| 30 | 96589 | 96579 | 10 | 95583 | 95588 | —05 | ..... | 94395 | .... | .09 | .05 | .... |
| 35 | 95877 | 95886 | —09 | 94722 | 94682 | +40 | ..... | 93453 | .... | .07 | .30 | .... |
| 40 | 95034 | 95066 | 32 | 93777 | 93781 | —04 | ..... | 92402 | .... | .20 | .03 | .... |
| 45 | 94080 | 93994 | +86 | 92752 | 92733 | +19 | 91388 | 91303 | +85 | .50 | .11 | 0.50 |
| 50 | 93048 | 93047 | 01 | 91678 | 91682 | —04 | 90299 | 90259 | 40 | .01 | .02 | .21 |
| 55 | 91983 | 92039 | —56 | 90570 | 90605 | —35 | 89141 | 89044 | 97 | .28 | .17 | .48 |
| 60 | 90885 | 90909 | 24 | 89446 | 89474 | 28 | 88005 | 87962 | 43 | .11 | .12 | .20 |
| 65 | 89757 | 89791 | 34 | 88299 | 88338 | 39 | 86800 | 86763 | 37 | .15 | .17 | .16 |
| 70 | 88607 | 88649 | 42 | 87127 | 87180 | 53 | 85603 | 85582 | 21 | .17 | .21 | .08 |
| 75 | 87459 | 87496 | 37 | 85951 | 85974 | 23 | 84316 | 84386 | —70 | .14 | .09 | .27 |
| 80 | 86250 | 86325 | 75 | 84761 | 84834 | 73 | 83188 | 83191 | 03 | .28 | .27 | .01 |
| 85 | 85040 | 85111 | 71 | 83520 | 83561 | 41 | 81946 | 81975 | 29 | .24 | .14 | .10 |
| 90 | ..... | 83840 | .... | ..... | 82310 | .... | ..... | 80722 | .... | .... | .... | .... |
| 95 | ..... | 82522 | .... | ..... | 80974 | .... | ..... | 79385 | .... | .... | .... | .... |
| 100 | ..... | 81190 | .... | ..... | 79539 | .... | ..... | 78013 | .... | .... | .... | .... |

104. It will be seen by inspection of the columns of differences, in the table just given, that the greatest discrepancy amounts to one-half of a per cent. only, which happens in three instances; while the mean difference is less than one-fourth of a per cent. This may be in part, if not wholly, accounted for by the fact that Delezennes used alcohol and water which had not been deprived of air, (see 82, words in italic,) but the difference itself is in every case, except the three just mentioned, too trifling to be worthy of consideration for practical purposes.

105. To render the correspondence of the two sets of data more evident, and any errors apparent, I caused them to be represented each by a curve. The two curves, (see PLATE A, herewith submitted,) indicate, by their similarity of form, the general accordance of the fundamental experiments; while the irregularities of that for the results of Delezennes, which occur at the points corresponding to the three cases of maximum discrepancy, clearly prove that in those instances Delezennes is in error.

106. Having thus shown that the results of Delezennes confirm those of Messrs. Gilpin and Blagden in a very remarkable manner, I next sought to verify the tables of Tralles. For this purpose, I caused the fundamental data in table VII. to be deduced from those of table IV.; the requisite numerical calculations were made by my friend and assistant, Mr. Reynolds, who had also performed those required by the last table. The following comparative table gives the result of this verification:

TABLE XXVII.

| Per cent. by vol. | Specific gravity. Tralles. | Specific gravity. Reynolds. | Per cent. by vol. | Specific gravity. Tralles. | Specific gravity. Reynolds. |
|---|---|---|---|---|---|
| 0 | 9991 | 99910 | 55 | 9234 | 92341 |
| 5 | 9919 | 99195 | 60 | 9126 | 91266 |
| 10 | 9857 | 98570 | 65 | 9013 | 90128 |
| 15 | 9802 | 98021 | 70 | 8892 | 88923 |
| 20 | 9751 | 97510 | 75 | 8765 | 87650 |
| 25 | 9700 | 97000 | 80 | 8631 | 86307 |
| 30 | 9646 | 96453 | 85 | 8488 | 84880 |
| 35 | 9583 | 95833 | 90 | 8332 | 83316 |
| 40 | 9510 | 95104 | 95 | 8157 | ..... |
| 45 | 9427 | 94274 | 100 | 7939 | ..... |
| 50 | 9335 | 93351 | ... | .... | ..... |

107. Among the tables of results in the preceding chapter those of Tralles, Gay Lussac, Gouverain, and Meissner, are all which give directly the per cents. by volume for liquors of different specific gravities. To show to what extent they correspond, they were all reduced to the common temperature of 60° Fahrenheit,

and to the same scale of water taken as unity at its maximum density.

In this manner the results were obtained which are embodied in the first of two following tables, marked table XXVIII.; as the specific gravities of Tralles are already referred to the temperature 60° Fahrenheit, and to the maximum density of water as unity, they were merely copied from table VII.

The second of these tables, marked table XXIX., was computed from the first by means of the general formula,

$$p = xy,$$

given in my former report.* It shows the differences which would occur, if any one series of the fundamental data in the first table be used instead of another.

By comparing the second column of table XXIX. with that of table XI., it appears that the latter, computed by Tralles, is confirmed by these calculations, which I caused to be made by two persons independently to obviate errors. Also, it is evident that while the results of Tralles and Gay Lussac accord very closely, they differ considerably from those of Gouvernain and Meissner; which, by the method of curves, (see plate C, herewith submitted,) are found to be improbable, and, therefore, not to be depended upon or considered worthy of particular credit.

TABLE XXVIII.

| Per cent. of alcohol by volume. | Specific gravity at 60° F. | | | |
|---|---|---|---|---|
| | Tralles. | Gay Lussac. | Gouvernain. | Meissner. |
| 100 | .7939 | .7935 | .7968 | .7938 |
| 95 | .8157 | .8156 | ..... | .8118 |
| 90 | .8332 | .8334 | .8328 | .8298 |
| 85 | .8488 | .8489 | ..... | .8438 |
| 80 | .8631 | .8633 | 8609 | .8577 |
| 75 | .8765 | .8766 | ..... | .8697 |
| 70 | .8892 | .8895 | .8870 | .8837 |
| 65 | .9013 | .9014 | ..... | .8966 |
| 60 | .9126 | .9123 | .9110 | .9076 |
| 55 | .9234 | .9235 | ..... | .9196 |
| 50 | .9335 | .9336 | .9322 | .9305 |
| 45 | .9427 | .9428 | ..... | .9404 |
| 40 | .9510 | .9511 | .9504 | .9493 |
| 35 | .9583 | .9583 | ..... | .9581 |
| 30 | .9646 | .9645 | .9647 | .9640 |
| 25 | .9700 | ..... | ..... | .9697 |
| 20 | .9751 | ..... | .9750 | .9756 |
| 15 | .9802 | ..... | ..... | .9795 |
| 10 | .9857 | ..... | .9858 | .9854 |
| 5 | .9919 | ..... | ..... | .9923 |
| 0 | .9991 | ..... | ..... | ..... |

*Sen. Doc. No. 165, 18th Cong., 2d sess., p. 52; and above, see p. 55.

TABLE XXIX.

| Per cent. of alcohol by volume. | Corresponding lengths of the stem, which would be immersed at 60° F. | | | |
|---|---|---|---|---|
| | Tralles. | Gay Lussac. | Gouvernain. | Meissner. |
| 100 | 25.9604 | 26.0239 | 25.5020 | 25.9763 |
| 95 | 22.5941 | 22.6091 | ..... | 23.1830 |
| 90 | 20.0192 | 19.9904 | 20.0768 | 20.5110 |
| 85 | 17.8134 | 17.7995 | ..... | 18.5115 |
| 80 | 15.8614 | 15.8346 | 16.1575 | 16.5909 |
| 75 | 14.0901 | 14.0771 | ..... | 14.9822 |
| 70 | 12.4606 | 12.4227 | 12.7396 | 13.1606 |
| 65 | 10.9508 | 10.9385 | ..... | 11.5325 |
| 60 | 9.5770 | 9.5530 | 9.7695 | 10.1807 |
| 55 | 8.2954 | 9.2837 | ..... | 8.7429 |
| 50 | 7.1237 | 7.1123 | 7.2731 | 7.4691 |
| 45 | 6.0783 | 6.0670 | ..... | 6.3377 |
| 40 | 5.1525 | 5.1414 | 5.2189 | 5.3408 |
| 35 | 4.3515 | 4.3515 | ..... | 4.3732 |
| 30 | 3.6699 | 3.6807 | 3.6892 | 3.7344 |
| 25 | 3.0928 | ..... | ..... | 3.1247 |
| 20 | 2.5535 | ..... | 2.5641 | 2.5810 |
| 15 | 2.0199 | ..... | ..... | 2.0929 |
| 10 | 1.4507 | ..... | 1.4405 | 1.4816 |
| 5 | 0.8166 | ..... | ..... | 0.7760 |
| 0 | 0.0901 | ..... | ..... | ..... |

108. To complete the comparison of the data of Tralles and Gay Lussac, it was necessary that the two following tables should be constructed: one, marked table XXX., showing the indications of their respective hydrometers at different temperatures; and the other, marked table XXXI., giving the corresponding specific gravities. Those of Tralles have been taken directly from table XII., but those of Gay Lussac were computed by means of the general formula,

$$p = xy,$$

from the corresponding data of the table in section ninety-three. It is not to be presumed that the numbers of Gay Lussac should be correct to the tenth of a per cent., any more than those of Tralles, (see section sixty-seven;) the specific gravities which I have deduced from his results may, therefore, vary in the fourth, and sometimes even in the third, place of decimals, without indicating probable errors. If this be borne in mind, the numbers of table XXXI. will appear to be in very close accordance; and the researches of these two philosophers should, therefore, be considered confirmatory of each other. Provided, however, that, as Berzelius asserts, (see section eighty-nine,) Gay Lussac based his tables upon original and independent data, and not upon those of Gilpin and Blagden.

## TABLE XXX.

*Comparative indications of the alcoholometers of Gay Lussac and Tralles, at different temperatures.*

| 30°. | | 40°. | | 50°. | | Per ct. at 60° Fahr. | 70°. | | 80°. | |
|---|---|---|---|---|---|---|---|---|---|---|
| G. Lussac. | Tralles. | G. Lussac. | Tralles. | G. Lussac. | Tralles. | | G. Lussac. | Tralles. | G. Lussac. | Tralles. |
| 9.1 | 9.1 | 9.2 | 9.1 | 9.5 | 9.3 | 10 | 11. | 11.0 | 12.2 | 12.3 |
| 16.5 | 16.5 | 17.6 | 17.4 | 18.8 | 18.5 | 20 | 22.0 | 21.8 | 23.8 | 23.8 |
| 23.8 | 23.5 | 25.8 | 25.7 | 28.0 | 27.7 | 30 | 32.5 | 32.2 | 34.4 | 34.5 |
| 33.3 | 33.0 | 35.4 | 35.4 | 38.0 | 37.8 | 40 | 42.4 | 42.2 | 44.3 | 44.3 |
| 43.7 | 43.7 | 46.0 | 45.8 | 48.1 | 47.9 | 50 | 52.2 | 52.0 | 54.2 | 54.0 |
| 54.5 | 54.2 | 56.2 | 56.2 | 58.3 | 58.1 | 60 | 62.1 | 61.9 | 64.0 | 63.8 |
| 64.8 | 64.6 | 66.6 | 66.4 | 68.4 | 68.2 | 70 | 71.9 | 71.7 | 73.7 | 73.5 |
| 75.2 | 75.0 | 76.7 | 76.6 | 78.5 | 78.4 | 80 | 81.8 | 81.7 | 83.3 | 83.2 |
| 85.8 | 85.6 | 87.2 | 87.1 | 88.7 | 88.6 | 90 | 91.5 | 91.4 | 92.7 | 92.7 |

## TABLE XXXI.

*Specific gravities of various mixtures at different temperatures, calculated from the tables of Gay Lussac and compared with those of Tralles.**

| Per ct. of alcohol. | 30° F. | | 40° F. | | 50° F. | | 60° F. | | 70° F. | | 80° F. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tr. | G. L. | Tr. | G. L. | Tr. | G. L. | Tr. | G. L. | Tr. | G. L. | Tr. | G. L. |
| 30 | 9715 | 9718 | 9694 | 9694 | 9671 | 9670 | 9646 | 9615 | 9619 | 9617 | 9590 | 9588 |
| 40 | 9609 | 9598 | 9577 | 9577 | 9544 | 9541 | 9510 | 9511 | 9474 | 9476 | 9438 | 9438 |
| 50 | 9449 | 9453 | 9413 | 9416 | 9374 | 9376 | 9335 | 9336 | 9294 | 9297 | 9253 | 9253 |
| 60 | 9249 | 9250 | 9210 | 9213 | 9163 | 9164 | 9126 | 9128 | 9083 | 9086 | 9039 | 9039 |
| 70 | 9021 | 9000 | 8980 | 8967 | 8936 | 8938 | 8892 | 8895 | 8847 | 8852 | 8801 | 8802 |
| 80 | 8764 | 8756 | 8721 | 8722 | 8676 | 8677 | 8631 | 8633 | 8585 | 8586 | 8538 | 8537 |
| 90 | 8469 | 8469 | 8423 | 8421 | 8379 | 8378 | 8332 | 8334 | 8285 | 8286 | 8238 | 8237 |

* The abbreviations Tr. and G. L. are substituted in the table for the words Tralles and Gay Lussac.

109. It is evident that we might multiply comparisons of the numerous data contained in the preceding chapter, to an almost indefinite extent. As, however, a sufficient number has been given to show that the results of Gilpin, Delezennes, Tralles, and Gay Lussac, strongly confirm each other; and as nothing but a little arithmetic and simple algebra is requisite to make similar comparisons of the weighings of Gilpin and Delezennes with those of Messrs. Fownes and Drinkwater, I shall add only one more table.

This table, marked table XXXII., is designed to facilitate the calculation of the equivalent per cent. by volume, at 60° Fahr., for any given per cent. by weight, and vice versa. The second column was deduced from table VII. of Tralles, by means of a simple algebraical formula, expressing the ratio of the volume of the alcohol contained by any spirituous liquor to the volume of the liquor itself, as a function of their respective densities and masses,

$$p = \frac{d}{D} v ;$$

$p$ denoting the ratio of the masses, $v$ the ratio of the volumes, and $D$ $d$ are the densities. The fourth column was then obtained from the second by interpolation.

TABLE XXXII.

*Comparison of the per cents. by weight with those by volume, at 60° Fahr.*

| Per cent. by volume. | Per cent. by weight. | Per cent. by weight. | Per cent. by volume. |
|---|---|---|---|
| 1 | 0.796 | 1 | 1.256 |
| 2 | 1.594 | 2 | 2.509 |
| 5 | 4.002 | 5 | 6.247 |
| 10 | 8.054 | 10 | 12.416 |
| 15 | 12.149 | 15 | 18.520 |
| 20 | 16.283 | 20 | 24.565 |
| 25 | 20.462 | 25 | 30.550 |
| 30 | 24.691 | 30 | 36.450 |
| 35 | 28.995 | 75 | 42.248 |
| 40 | 33.392 | 40 | 47.915 |
| 45 | 37.899 | 45 | 53.432 |
| 50 | 42.523 | 50 | 58.792 |
| 55 | 47.286 | 55 | 63.973 |
| 60 | 52.196 | 60 | 68.971 |
| 65 | 57.255 | 65 | 73.793 |
| 70 | 62.498 | 70 | 78.402 |
| 75 | 67.932 | 75 | 82.803 |
| 80 | 73.586 | 80 | 86.973 |
| 85 | 79.502 | 85 | 90.878 |
| 90 | 85.755 | 90 | 94.455 |
| 95 | 92.461 | 95 | 97.609 |
| 100 | 100.000 | 100 | 100.000 |

## CHAPTER II.

### NEW EXPERIMENTS ON THE SPECIFIC GRAVITIES OF ALCOHOLIC LIQUORS.

110. These experiments were designed to attain two objects: 1st, to test the accuracy of the work and statements of others; and 2dly, to enable me to testify of personal knowledge, derived from carefully observed facts, concerning the real specific gravities of mixtures of alcohol and water, in various proportions, and at different temperatures; so that I should become responsible for the truth of any method which might be recommended to, and adopted by, the government. They were not intended to furnish results more exact than any heretofore obtained, nor to advance general science; but simply to constitute a set of confirmatory and independent inquiries, of sufficient accuracy for practical or revenue purposes.

It is very desirable, however, that a much more extended series of similar experiments should be made, with far superior apparatus, and all possible care and skill, which would form the basis of any system subsequently established by law, and be referred to in disputed or doubtful cases.

111. I commenced my experimental work by a thorough and careful examination of the apparatus which was to be employed. The fixed points and graduation of the thermometer were found to be correct, or at least apparently exact; and with reference to the hydrometers, it was ascertained that they were perfectly tight, so that no infiltration could occur; and also, that they were free from open joints or fissures in which bubbles of air might be retained by capillarity. This was done by immersing them entirely in freshly distilled water for several days, during which they were repeatedly inspected.

112. I had three excellent and complete sets of weights; one, a standard set by Mr. Hassler, which extends from one tenth of an ounce to ten ounces troy, belonging to the office of weights and measures, and entrusted to me for these researches; and two similar sets, copied from those just mentioned by Mr. Duffey, a skilful philosophical instrument maker of Philadelphia. These weights I compared carefully with each other, and with those used in the United States mint for weighing gold, which were adjusted, only a few days before, by comparison with the mint pound, which is by law *the standard unit of weight* of the United States. Only one of the weights by Duffey, which had also suffered from accidental injury, was found to be appreciably in error; it was, therefore, discarded.

A series of decimal fractional weights, from 0 50 to 0.00001 of the troy ounce, adjusted for the purpose by Mr. Saxton, in the office of weights and measures, had also been furnished me. Of

these, Mr. Duffey made two copies which were found to agree with each other, with those of Mr. Saxton, and with similar weights of the United States mint. This comparison was made for me in the assay office of the mint, by my friend and colleague, J. R. Eckfeldt, esq., Assayer, who used for the purpose one of the extremely sensible and delicate assay balances constructed by Mr. Saxton for that office.

In some few instances I also made use of several British troy pound weights, which were procured in 1823 from the royal mint of England, and had been adjusted to the standard of that mint for the mint of the United States, as set forth in the official certificate accompanying them. They were all found to be considerably lighter than the United States standard, and corrections were carefully determined to reduce them to that standard, which were applied whenever they were used. Some of these weights were slightly worn, but others were in perfect preservation; it is, therefore, evident that the standard of the British mint is lighter than that of the United States, the difference amounting, according to my experiments, to about 0.001 ounce troy in three pounds, or 0.00033 in a single pound.

113. I was provided with two balances, made by Duffey; a small and delicate one, designed for use in travelling, and which was constructed expressly for and employed in my analyses of the sugar cane in the island of Cuba; and a larger balance, formerly used by me for making the definite solutions required in analyses of saccharine substances by circularly polarized light. Both of these instruments were in perfect order. The small one is susceptible of convenient and prompt adjustment by screw motions, except with reference to the relative vertical positions and the parallelism of its knife edges; these were, therefore, examined and found to be in the same horizontal plane and very nearly parallel; so that weighing with this balance possesses all requisite accuracy. Its chief fault is that it is not provided with suitable mechanical arrangements for checking its oscillations, so that much time and patience is needed in using it.

The large balance had no adjusting screws, all its parts being rigidly fastened together. It was, therefore, subjected to a strict and careful examination, particularly with reference to the adjustment of its knife edges. This was done by bringing those edges into close contact with long and perfectly straight steel rulers, by which means their directions were virtually prolonged several feet; when the distances between the rulers are measured at different points, any want of parallelism becomes very evident. I thus found that the knife edges of the large balance were not parallel, either vertically or horizontally; of course, very exact weighings could not be made with it, nor could confidence be placed in its indications, unless Borda's method of double weighing were followed. The central knife edge was also slightly below the horizontal plane in which the knife edges of the scale pans were situated; the sensibility would, therefore, increase with the load until the

centre of gravity should lie above the fulcrum, when the equilibrium becomes unstable and the indications may be false. To render my experiments free from all errors due to the defects of workmanship of this balance, I employed Borda's method in every instance, taking great pains to avoid disturbing the positions of the knife edges when the body was removed and the equivalent weights substituted. And in order to ascertain whether it would have caused any difference, if, by accidental neglect or otherwise, the common method of weighing had been followed, instead of that of Borda, the counterpoises were always formed of weights; and not of substances of unknown masses, as is often done.

This mode of operating possesses, in my opinion, great advantages; it facilitates the manipulations by pointing out, either exactly or very nearly, the weights to be substituted for the body; and it renders errors much less probable, by causing the operator to select the very weights which his reading of the counterpoise weights calls for, so that he is compelled to verify his observations as he proceeds.

Notwithstanding the want of parallelism of the knife edges of Duffey's balance, I did not find that it produced a perceptible difference in a single instance whether the weighing was done directly or by Borda's method. The results are, therefore, exact to the full extent of the approximation to which the weighings were carried; or, in other words, they are not in error to the extent of 0.001 ounce troy, in any instance.

114. For making standard alcoholic mixtures, it was necessary that I should use considerable quantities, and that they should be as free as possible, not only from actual error, but from just suspicion of error. I therefore abandoned Duffey's balance, on account of the above mentioned imperfections, and employed one by Saxton, belonging to the United States mint, which is of very superior workmanship, and entitled to entire confidence. So excellent was this balance, that it was altogether unnecessary to follow Borda's method; and, as the weights belonging to it had been adjusted by a very skilful and experienced workman only a few days before, I merely compared some of them with each other, and with those of Duffey copied from the weights of Mr. Hassler, after which I used them alone, or in combination with Duffey's weights, as was most convenient. The greatest possible inaccuracy in any of those mixtures, due to instrumental errors, cannot, I think, exceed the ten thousandth of an ounce, or the five hundred thousandth of its own weight.

115. It is due to Mr. Duffey that I should here state that the large balance to which reference is made in what I have said above, was not designed for other than comparatively rough determinations. It was a cheap instrument, upon which he had expended but little time; and if its cost be taken into consideration, as well as its performance, I may confidently assert that better work could not be done by any one. That it should have been used at all, for such work as the present, is proof that it possesses great superiority

over any balances of like cost and pretensions. Nor would it be just to compare it with any instrument, made either in this country or in Europe, for which even a medium price may have been paid; its cost having been, in fact, but little more than that usually paid for a pair of ordinary grocer's scales.

116. *Preparation of pure alcohol.*—Pure alcohol and pure water were both needed for making the standard mixtures. The latter required only to be distilled under my immediate notice and with proper care; but it was much more difficult to obtain the former in sufficient quantity than I anticipated. Messrs. Powers and Weightman, skilful manufacturing chemists of Philadephia, undertook to supply me with alcohol of the highest degree of strength they could prepare. At first, they were unable to make it stronger than 97 per cent., but subsequently they succeeded in bringing it to the strength of 100 per cent., indicated by the alcoholometers of Tralles and Gay Lussac.

117. With several gallons of 97 per cent. alcohol, furnished by the above mentioned gentlemen, I commenced my own attempts to deprive it *entirely* of water. By repeated distillations with chloride of calcium, I could not obtain a higher degree of strength than 99 per cent., though every precaution was taken to prevent absorption of moisture from the air and apparatus; I therefore abandoned that reagent; with which I did not indeed expect better success from the first, because Dumas speaks of it as inefficient, by reason of its affinity for alcohol being nearly as great as that which it has for water.* With lime, however, I succeeded, after six or seven distillations, in bringing a small quantity to the desired indication of 100 per cent., according to a hydrometer of Tralles made by Greiner, of Berlin. Having re-distilled this liquor several times over lime without perceptible change of density, I considered it to be as strong as possible, or absolute; and, therefore, desisted from further attempts to obtain it of less specific gravity. These distillations were all conducted with care; the still being heated gently by means of a water-bath; and every possible means being taken to use perfectly dry apparatus, and to prevent the moisture of the atmosphere from being absorbed. They are tedious, and consume much time by reason of the necessity of their frequent repetition; and they cannot be conducted with safety in glass vessels, because the swelling of the lime as it slacks, breaks the vessels. In this manner I lost a large quantity of alcohol, and the labour of nearly a week, which had been expended upon it; after which occurrence, all my distillations were carried on in metallic vessels.

118. Since these experiments were made, those of Mr. Drinkwater,† have become known to me, which give for absolute alcohol

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* Traite de Chim. appliq. aux Arts, t. 5, p. 458.
† See section 98; or the Lond. and Ed. Phil. Mag. for February, 1848.

a much lower specific gravity, as the result of attention to some slight precautions which have heretofore been overlooked by every one else. I therefore respectfully suggest that this subject be reserved for further investigation.

119. I did not take the specific gravity of the absolute alcohol which I had prepared; for the reason that, about the same time, Messrs. Powers and Weightman succeeded in making a similar article in large quantity, which was apparently of the same strength or specific gravity, according to the hydrometer of Tralles above mentioned. If there was any difference between them it was scarcely appreciable, and in favor of the alcohol made by them. As I needed a very considerable quantity, to prepare which would have cost me much time and labor with such apparatus as I possessed, I considered the success of Messrs. Powers and Weightman very fortunate for me, and was glad to adopt their alcohol as the standard alcohol of my subsequent investigations, in preference to that which I had myself prepared.

120. Both my own alcohol and that of Messrs. Powers and Weightman had a peculiar and unpleasant taste and odor, which was readily removed by filtration through coarsely divided and freshly calcined animal charcoal. As the specific gravity of the alcohol, indicated by a delicate hydrometer, was not changed in the least by this filtration, the temperatures being the same, I concluded that the impurity to which that taste and smell was owing, whatever it might be, existed in it in such small quantity as to produce no sensible effects of a physical nature, and that it might, therefore, be disregarded. Although I cannot say, with any certainty, what is the source of the disagreeable flavor of alcohol thus concentrated, a flavor resembling somewhat that of cyanogen, I have but little doubt that it is to be attributed to reactions between the lime and vegetable oils which exist in small quantity in all spirituous liquors.

121. *Preparation of standard mixtures.*—Having procured alcohol of such strength and purity that for all ordinary practical purposes it might be considered absolute, I proceeded to make with it, and with freshly distilled water, two sets of mixtures, one constituting a series varying successively by ten per cent. 0, 10, 20, 30, etc., of which pure water and pure alcohol are the extremes, and the other giving the intermedite proportions 5, 15, 25, 35, etc., per cent. by weight of alcohol; the weighings being made, as above mentioned, (114,) with the balance and weights used for weighing gold in the United States mint, and with extreme care.

122. Each mixture was made in the same conterpoised bottle, which was rinsed out with distilled water, several times, before each operation; in order to remove all traces of the liquor which had been in it before. When the counterpoise to the bottle was prepared, the latter was as dry as it was possible to make it by wip-

ing and by heat, both externally and internally. Before putting the mixtures into the bottles intended for them, they were well shaken for several minutes, in different directions, to insure incorporation and homogeneity, and the bottles were well rinsed with two or three successive portions of the liquors they were to contain before these were put into them; the portions used for rinsing being first poured out and thrown away.

123. The following table, marked TABLE XXXIII., comprises the data for the first series of mixtures, 10 to 90 per cent. inclusive.

TABLE XXXIII.

| Apparent per cent. of alcohol. | Apparent weights in oz. | | Reduced weights. | | Reduced per cent. of alcohol. |
|---|---|---|---|---|---|
| | Alcohol. | Water. | Alcohol. | Water. | |
| 10 | 5 | 45 | 5.00690 | 45.04770 | 10.0028 |
| 20 | 10 | 40 | 10.01380 | 40.04240 | 20.0052 |
| 30 | 15 | 35 | 15.02070 | 35.03710 | 30.0067 |
| 40 | 20 | 30 | 20.02760 | 30.03180 | 40.0077 |
| 50 | 24 | 24 | 24.03312 | 24.02544 | 50.0080 |
| 60 | 27 | 18 | 27.03726 | 18.01908 | 60.0076 |
| 70 | 28 | 12 | 28.03864 | 12.01272 | 70.0066 |
| 80 | 34 | 8.5 | 34.04692 | 8.50901 | 80.0051 |
| 90 | 36 | 4 | 36.04968 | 4.00424 | 90.0028 |

124. The mean observed temperature of the room, at the time of making the above mixtures, was very nearly 20° centigrade. I was not provided with a good barometer, and did not, therefore, observe the atmospheric pressure. In the reductions it is assumed to have been 29.85 inches; a mean value obtained from the observations made at similar periods of the year and day at the magnetic observatory of the Girard college; and which is probably very nearly the pressure which would have been observed at the time and in the mint. Moreover, a correction for the barometer was unimportant, because the error which would have been caused by neglecting it entirely, or by using the normal pressure 29.93 inches, would have produced no material difference in the results. Indeed, it is evident, from the last column of the preceding table, that for all practical or scientific purposes we may substitute the apparent for the reduced per cent. of any of these mixtures; the maximum difference being only 0.008, or nearly one hundredth of a per cent., a quantity which is beyond the power of measurement of the most exact chemical analysis.

125. The specific gravity of one of the brass weights was found to be 8.466, apparently; which value was employed in the reductions, water being taken as unity at the same temperature, and alcohol assumed to be 0 8. To have used more exact values would have rendered the calculations more laborious, without compensa-

ting advantages or increased accuracy; the probable errors of the weighings being much greater than the differences, which may, indeed, be considered as infinitesimal, and, therefore, be rejected in the reductions.

126. Immediately before making the mixtures of TABLE XXXIII., the specific gravity of the alcohol to be used for them (some of that made by Messrs. Powers and Weightman) was determined by means of a large brass hydrometer, and found to be as follows:

| | Apparent. | Reduced. |
|---|---|---|
| At 14°.5 C. | 0.796583 | 0.796121 |
| 14°.4 | 0.796640 | 0.796182 |
| 14 .4 | 0.796655 | 0.796196 |
| 15°.0 | 0.796102 | 0.795618 |

water being taken as unity at its maximum density, or at the temperature 4°.2 centig.; and the reduced specific gravities differing from the apparent, by reason of the correction for the dilatation of the brass of which the hydrometer was made. The normal volume being assumed to be that which it would have at 4°.2, or when floating in water of maximum density, and the coefficient of linear dilatation, 0.000018782, obtained by MM. Lavoisier and Laplace, being adopted. In the same alcohol, at the temperature 14°.4 cent., the alcoholometer of Tralles, by Greiner, indicated 99½ per cent. by volume; its attached thermometer of correction reading — 0.5, or giving for the strength, at 60° Fahrenheit, 99.8 per cent. by volume.

127. In weighing both the water and the alcohol, the desired quantity was first calculated, and the required weights were put into one of the scale pans with the counterpoise of the bottle. Into the other, the bottle and a two ounce weight were placed; the liquid was then poured freely into the bottle, through a funnel, until that side of the balance sunk. The two ounce weight being removed, the remainder to be added was introduced by means of a pipette, with great care, and towards the close, by single drops. If the last drop was slightly excessive, the exact weight was obtained by absorbing very small portions with a capillary tube of glass. In this manner, the equilibrium was rendered perfect, and all errors avoided which would sensibly affect the balance; these weighings are, therefore, as exact as the workmanship of the balance and weights, which was, as I have already mentioned, very superior, (§ 114,) could give.

128. The quantities of the mixtures of TABLE XXXIII. being greater than were needed, the following mixtures were made from them; compounding them in the proportions indicated, and with the view of making a series containing 5, 15, 25, 35, etc., per cent., for its successive terms.

| Ounces. | Per cent. | | Ounces. | Per cent. | Ounces. | Per cent |
|---|---|---|---|---|---|---|
| 15 | of 10 | with | 15 | of 0* | = 30 | of 5 |
| 7.5 | " 20 | " | 7.5 | " 30 | = 15 | " 25 |
| 7 | " 30 | " | 7 | " 40 | = 14 | " 35 |
| 6 | " 40 | " | 6 | " 50 | = 12 | " 45 |
| 6 | " 50 | " | 6 | " 60 | = 12 | " 55 |
| 5 | " 60 | " | 5 | " 70 | = 10 | " 65 |
| 6 | " 80 | " | 6 | " 90 | = 12 | " 85 |

This series was not designed to constitute one of *standard* mixtures, but merely a link of comparison and verification between the two sets of standard mixtures referred to in section 121, and of which the first is given in TABLE XXXIII.; the second being comprised in TABLE XXXIV. below. To distinguish them I shall call them *secondary mixtures*. They were made with Duffey's large balance, instead of the mint balance by Saxton, used for the standard mixtures; and are, therefore, not as exact, though the probable error cannot, I believe, exceed 0 001 oz. apparent weight, or 0.0001 apparent per cent., in any instance.

129. The second series of standard mixtures were made on a subsequent day, at the same hour, and in precisely the same manner as the first. The building being heated by a furnace, and kept at a uniform temperature from day to day, the observed mean temperature was very nearly 20° C, on both occasions. Hence the coefficients of reduction did not vary for the two series.

The precise alcohol used for compounding the first mixtures being exhausted by them, some furnished in a separate vessel by the manufacturers, at the same time and as the same article, had to be used for the second series of mixtures. And to avoid the possibility of error, which would arise if these two alcohols were not the same, the specific gravity of the second was taken as that of the first had been, (section 125,) with the same hydrometer, and with the following result:

At 15.°4 cent. apparent specific gravity 0.795903; which gives for the reduced specific gravity 0.795401.

The same liquor gave on two other occasions at the

| | | | |
|---|---|---|---|
| Temp. 16.°9 C. | apparent specific grav. | .794556, or reduced | .793987 |
| " 17.°9 | " " | .793692 " | .793079 |
| Correction for 1° cent..... | | .000864 | .000908 |

If we apply similar corrections to the specific gravities of this alcohol obtained at 15.°4 cent., in order to reduce them to 14.°4 cent., the temperature at which two of the determinations of the density of the first alcohol were experimentally made, we have,

At 14.°4 cent., the apparent specific gravity.... 0.796767
" the reduced " .... 0.796309;

* Water.

which differ by unity in the fourth place of decimals, from the densities, (section 125,) obtained for the first parcel of alcohol at the same temperature. It is not improbable that this difference is owing to absorption of aqueous vapor from the atmosphere, which had occurred during the interval; and which can scarcely be prevented, however tightly the containing vessel may be stopped.

The following table embraces the observed and reduced results for this second series of standard mixtures:

TABLE XXXIV.

| Apparent per cent. of alcohol. | Apparent weight in ounces. | | Reduced weights. | | Reduced per cent. |
|---|---|---|---|---|---|
| | Alcohol. | Water. | Alcohol. | Water. | |
| 5 | 2.5 | 47.5 | 2.50345 | 47.55035 | 5.0018 |
| 15 | 7.5 | 42.5 | 7.51035 | 42.54505 | 15.0041 |
| 25 | 12.5 | 37.5 | 12.51725 | 37.53975 | 25.0060 |
| 35 | 17.5 | 32.5 | 17.52415 | 32.53445 | 35.0072 |
| 45 | 22.5 | 27.5 | 22.53105 | 27.52915 | 45.0078 |
| 55 | 22.0 | 18.0 | 22.03036 | 18.01908 | 55.0079 |
| 65 | 26.0 | 14.0 | 26.03588 | 14.01484 | 65.0073 |
| 75 | 30.0 | 10.0 | 30.04140 | 10.01060 | 75.0060 |
| 85 | 34.0 | 6.0 | 34.04692 | 6.00630 | 85.0041 |

No mixture corresponding to 95 per cent. was made, because the supply of alcohol was insufficient; its preparation was, consequently, deferred.

In commerce, spirit of 95 per cent. is very seldom met with; and, for practical purposes, the above table may, therefore, be considered almost complete.

130. Having prepared the preceding mixtures with all possible accuracy and care, I proceeded to determine their specific gravities by means of a hydrometer of Fahrenheit, made of brass, with the exception of its stem, which was of steel, that it might combine strength with minimum volume. The apparent weight of the whole instrument at 18.°8 cent., with a barometric pressure of 29.9 inches nearly, taken with the mint balance, was 4.711 ounces troy. That of its dish, and the portion of the stem above the index point, 0.252, very nearly. To sink it in water at 17.°9 cent., the weight required was 1 3153 ounces; and from these data I obtain 4.7177 as the absolute or reduced weight of the instrument.

131. With freshly distilled water, this hydrometer gave the following results:

| Weight required to be added. | Total reduced weight. | Temperature. | Apparent specific gravity. | Reduced specific gravity. |
|---|---|---|---|---|
| 1.3153 | 6.0328 | 17.9 C. | 0.999366 | 0.998589 |
| 1.3140 | 6.0315 | 19.4 | 0.999151 | 0.998296 |
| 1.3143 | 6.0318 | 19.9 | 0.999201 | 0.998318 |

In the reduced specific gravities, both the volume of the instrument is assumed to be that which it would have at 4°. 2 centigrade, and corrections are applied for atmospheric buoyancy exerted upon the stem, the dish, and the added weights. The unit of density being assumed to be that of water at its maximum density. And, generally, in these investigations, it is to be understood, whenever it is not expressly stated, that similar reductions are made, and the same unit of density employed. The coefficient for the dilatation of brass, of MM. Lavoisier and Laplace, and the table of Despretz,* for the expansion of water, being used when necessary to make the reductions for which they are intended.

132. With the first series of standard mixtures, the following observed weights and reduced values were obtained:

| Per cent. | Weight added. | Total reduced weight. | Temp. of the spirit. | Apparent specific gravity. | Reduced specific gravity. | Temp. of the room. |
|---|---|---|---|---|---|---|
| | | | ° C. | | | ° C. |
| 10 | 1.2195 | 5.9370 | 17.4 | 0.983496 | 0.982752 | 18.8 |
| 20 | 1.1427 | 5.8602 | 17.3 | 0.970774 | 0.970030 | 18.8 |
| 30 | 1.0572 | 5.7747 | 17.6 | 0.956611 | 0.955888 | 18.5 |
| 40 | 0.9471 | 5.6646 | 17.7 | 0.938372 | 0.937657 | 18.5 |
| 50 | 0.8206 | 5.5381 | 18.5 | 0.917416 | 0.916675 | 18.7 |
| 60 | 0.6830 | 5.4006 | 18.0 | 0.894639 | 0.893940 | 18.7 |
| 70 | 0.5423 | 5.2599 | 18.0 | 0.871331 | 0.870666 | 18.5 |
| 80 | 0.3970 | 5.1146 | 18.1 | 0.847262 | 0.846596 | 18.5 |
| 90 | 0.2437 | 5.9613 | 18.3 | 0.821867 | 0.821242 | 18.5 |
| 100† | 0.0737 | 4.7914 | 18.4 | 0.793722 | 0.793082 | 18.5 |

It should be observed that the *reduced weights* are corrected for atmospheric buoyancy. The only difference between the *apparent* and the true or *reduced specific gravities* is, therefore, that in the latter the volume of the hydrometer is reduced to that which it would have at 4°. 2 cent., according to the coefficient of MM. Lavoisier and Laplace.

133. With the same mixtures, on a subsequent day, the following results were found:

* Ann. de Chim. et de Phys. t. 70, p. 1.
† This alcohol is probably slightly different from that used for the mixtures.

| Per cent. | Weight added. | Temp. Centig. | Reduced weight. | Apparent specific gravity. | Reduced specific gravity. |
|---|---|---|---|---|---|
| 10 | 1.2030 | 28°.4 | 5.9205 | 0.980763 | 0.979426 |
| 20 | 1.1146 | 28.95 | 5.8321 | 0.966120 | 0.964766 |
| 30 | 1.0140 | 29.7 | 5.7315 | 0.949454 | 0.948088 |
| 40 | 0.8946 | 30.1 | 5.6121 | 0.929675 | 0.928318 |
| 50 | 0.7630 | 30.2 | 5.4806 | 0.907892 | 0.906574 |
| 60 | 0.6367 | 27.7 | 5.3543 | 0.886969 | 0.885792 |
| 70 | 0.4975 | 27.3 | 5.2151 | 0.863910 | 0.862791 |
| 80 | 0.3504 | 27.5 | 5.0680 | 0.839542 | 0.838440 |
| 90 | 0.1995 | 26.8 | 4.9171 | 0.814544 | 0.813525 |
| 100 | 0.0297 | 27.1 | 4.7474 | 0.786433 | 0.785399 |
| 100 | 0.0323 | 26.7 | 4.7500 | 0.786863 | 0.785849 |

134. Similarly, the second series of standard mixtures gave:

| Per cent. | Weight added. | Temp. Centig. | Reduced weight. | Apparent specific gravity. | Reduced specific gravity. |
|---|---|---|---|---|---|
| 5 | 1.2615 | 19°.1 | 5.9790 | 0.990454 | 0.989623 |
| 15 | 1.1774 | 18.9 | 5.8949 | 0.976523 | 0.975711 |
| 25 | 1.0987 | 18.9 | 5.8162 | 0.963485 | 0.962685 |
| 35 | 0.9995 | 19.1 | 5.7170 | 0.947053 | 0.946254 |
| 45 | 0.8790 | 19.1 | 5 5965 | 0.927091 | 0.926368 |
| 55 | 0.7462 | 19.2 | 5.4638 | 0.905108 | 0.904347 |
| 65 | 0.6085 | 19.2 | 5.3261 | 0.882297 | 0.881552 |
| 75 | 0.4657 | 19.2 | 5.1833 | 0.858612 | 0.857914 |
| 85 | 0.3177 | 19.3 | 5.0353 | 0.834125 | 0.833419 |

135. In taking the specific gravities given above, all disturbing influences were cautiously guarded against—such as currents of air, change of temperature either of the room or apparatus, contact with the vessel, &c. In observing the temperatures, great care was taken to ascertain whether the liquid was homogeneous, and to allow the thermometer to attain its temperature of equilibrium, as well as to remove it before any change could have occurred by reason of external action. If time had permitted it, the number of observed results would have been much extended. As observations could only be made when the mean temperature of the room and the liquid was stationary, it would have required a year to obtain the specific gravities corresponding to the successive degrees of the thermometer, which intervene between the extremes of summer and winter temperature, in a climate so changeable as that of any city of the United States.

136. To render it evident to what degree of approximation the preceding data agree with those of M. Delezennes, (see § 82,) I have arranged the following comparative table:

| Per cent. | Sp. gravity. Delezennes, at 18° cent. | Sp. gravity. McCulloh, at 18° cent. | Difference. | Diff. of per cent. | Variation for 1° C., Delezennes. | Variation for 1° C., McCulloh. |
|---|---|---|---|---|---|---|
| 5 | 0.98970 | 0.98981 | 0.00011 | 0.076 | 0.000169 | ..... |
| 10 | 0.98249 | 0.98257 | .00008 | 0.061 | 0.000228 | 0.000302 |
| 15 | 0.97575 | 0.97599 | .00024 | 0.191 | 0.000320 | ..... |
| 20 | 0.96962 | 0.96971 | .00009 | 0.069 | 0.000420 | 0.000452 |
| 25 | 0.96300 | 0.96316 | .00016 | 0.106 | 0.000525 | ..... |
| 30 | 0.95576 | 0.95563 | .00013 | 0.075 | 0.000606 | 0.000653 |
| 35 | 0.94670 | 0.94700 | .00030 | 0.157 | 0.000676 | ..... |
| 40 | 0.93769 | 0.93743 | .00026 | 0.127 | 0.000740 | 0.000753 |
| 45 | 0.82721 | 0.92719 | .00002 | 0.009 | 0.000748 | ..... |
| 50 | 0.91670 | 0.91711 | .00041 | 0.175 | 0.000774 | 0.000863 |
| 55 | 0.90593 | 0.90539 | .00054 | 0.236 | 0.000867 | ..... |
| 60 | 0.89463 | 0.89394 | .00069 | 0.302 | 0.000769 | 0.000775 |
| 65 | 0.88327 | 0.88253 | .00074 | 0.312 | 0.000841 | ..... |
| 70 | 0.87169 | 0.87067 | .00102 | 0.435 | 0.000849 | 0.000947 |
| 75 | 0.85963 | 0.85895 | .00068 | 0.276 | 0.000864 | ..... |
| 80 | 0.84823 | 0.84661 | .00162 | 0.645 | 0.000871 | 0.000885 |
| 85 | 0.83550 | 0.83405 | .00145 | 0.578 | 0.000871 | ..... |
| 90 | 0.82299 | 0.82152 | .00147 | 0.522 | 0.000871 | 0.000908 |
| 100 | 0.79529 | 0.79335 | .00194 | 0.688 | 0.000882 | 0.000906 |

137. From this table it is evident that there is a very close correspondence between the results of M. Delezennes (§ 82) and my own. The differences, which are at first trifling, gradually increase to the last, as they should have done, by reason of the inferior strength of the alcohol he employed. As he used chloride of calcium instead of lime, (§ 74,) there can be no doubt that the alcohol he considered absolute, was but little if any over 99 per cent., (§ 117;) it is, moreover, of greater density than either of the values given for absolute alcohol by Lowitz, Meissner, Gay Lussac, Fownes, Drinkwater, and others, and must, therefore, be considered of lower quality. Assuming that the last result of the preceding table is exact, or that the difference between my alcohol and that of Delezennes amounted to 0.7 per cent. by weight nearly, the data furnished by his experiments become practically identical, or differ inappreciably, from mine, when the requisite corrections are applied.

138. I have selected the experiments of Delezennes in preference to those of others for this comparison, because it has already been shown in the preceding chapter that they accord very closely with, and therefore, confirm those of Gilpin and Blagden, (section 103,) and because the comparison could also be much more readily made with them than with the latter directly.

139. The differences between all three of these sets of experiments, when the reductions are performed, which are requisite for their reference to a single scale and to like circumstances, do not exceed a small fraction of a per cent., 0.2 or 0.3, except in a few particular cases, (section 104), which are such that the errors can readily be perceived and corrected.

140. We may, therefore, consider it *impossible that any system of determining the strength of liquors for revenue or scientific purposes, which may be based upon these independent and confirmatory results, obtained at different times, in different countries, and from alcohol derived from different substances, can be in error to a considerable, or even appreciable extent;* if that system be not arbitrarily or improperly devised.

And we may confidently recommend them to the government, as entitled to implicit confidence, both in reference to ordinary cases, and to such as may give rise to disputes and litigation.

The necessarily limited number of my experiments renders it, however, desirable that this work should be extended; and that every minute cause of error should be investigated, and, if possible, overcome in whatever researches may hereafter be made on this subject, trifling though such errors may seem. For that any scientific work, which may become the basis of operations arbitrarily established by law, may possess the only title which it can have to public confidence, it must be rigidly true.

141. The two last vertical columns of the preceding table shows how very important it is in these experiments to pay strict attention to temperature. For since a change amounting to a single degree of the centigrade thermometer produces a corresponding change of 0.0009 nearly, we must observe tenths of a degree with accuracy, if we would avoid serious errors.

This fact caused me to consider it even of more importance to measure the temperature with accuracy and minute care, than to carry the weighings to the extreme limit of sensibility of the most delicate balance; and I am confident that such inaccuracies as exist in the results of Messrs. Gilpin and Blagden are to be attributed rather to thermometric errors, than to any which might be supposed to have occurred in their weighings.

142. To render my own results as free as possible from errors of temperature, the following precautions were, in every case, strictly observed:

The mixtures, the hydrometer, the thermometer, and the glass vessel in which the specific gravities were taken, were all allowed to remain together in the same room for twenty-four hours. If the weather was very cold or damp, a small fire was kindled in the room, which was allowed to burn out without replenishment. The whole room, and every object in it, were thus brought as near as possible to a common temperature. Nor were windows, doors, &c., allowed to be opened, except for going in or out of the room, and that as seldom as possible.

When the specific gravities were taken, the temperature of the mixture was rendered uniform by shaking it well before pouring it from its bottle, and all air bubbles thus produced, or which were caused by pouring the liquid from the bottle were allowed to rise to the surface and break, before the hydrometer was immersed.

Before removing the hydrometer from the liquid, and as soon as

its proper load was ascertained, the thermometer was inserted—at first to the depth of a few inches only, and afterwards more and more until it nearly reached, but did not touch the bottom of the containing vessel; carefully keeping it, also, from contact with the side. In this manner it was easily perceived whether or not the temperature of the mass of the liquid, or of its successive horrizontal strata, was uniform. If any difference was observed, the hydrometer and thermometer were removed, and promptly wiped as dry as possible, after which they were allowed to rest until they should acquire the mean temperature of the room, and the observation was commenced anew after shaking the liquid thoroughly, in the vessel containing it—the top being covered either with a ground glass plate, or with a piece of sheet caoutchouc, protected from the hand by a towel.

In all the manipulations, care was taken to avoid contact between the naked hand, or any thing which could affect the temperature; the bottles, the containing glass vessel, the thermometer, and the hydrometer, being handled as little as possible, and always with interposed cotton towels.

When the hydrometer and thermometer were removed, and the liquid restored to its bottle, great care was taken to avoid such errors, as would certainly have arisen, if wet surfaces were exposed to the cooling influence of evaporation. For this purpose, they were taken successively from the liquid, and quickly wiped with two towels; and the glass vessel was similarly treated as soon as the liquid was poured from it; time being also allowed for the restoration of these instruments to the mean temperature, to avoid the possibility of error.

143. The thermometer employed was an exceedingly beautiful and delicate standard instrument, made by Greiner of Berlin, and which I had imported from Germany for these researches. It is divided, according to the centigrade scale, into degrees and fifths of a degree; the fifth of a degree occupies the space of about one twentieth of an inch. The tenth of a degree can, therefore, be observed with accuracy. It is scarcely necessary that I should say, that in the construction of this instrument irregularities of the tube were carefully attended to. The graduated scale is of glass: no errors can, therefore, occur from unequal expansion of the tube and scale. Before commencing my experiments, and once, also, during them, I verified the zero points of this instrument and another by the same artist, by immersing them in melting ice. They also agreed in their indications with each other, and with a French thermometer of my own, at higher temperatures. But I did not verify the boiling point of either; which should, perhaps, be done if the results of these experiments are considered worthy of any credit, beyond that which they were intended to derive from comparison with, and confirmation of, the work of others.

144. As a check, though probably a comparatively rough one, upon the preceding experiments, the following specific gravities

are taken with Duffey's large balance, by weighing a bottle filled successively with portions of the first series of standard mixtures, (see § 123, table XXXIII.,) and the *secondary* mixtures of § 128; the weighings were made both by Borda's method and in the ordinary way without causing perceptible differences. The mean temperature of the room was 18° cent. nearly; and the weight of the bottle, when dry and empty, was 8.975 ounces. Also, it weighed, when full of water, at 17°.5 cent., 17.124 ounces troy.

| Per cent. | Observed weight of bottle and liquid. | Temperature. | | Reduced weight of liquid. | Apparent specific gravity. | Reduced specific gravity. |
|---|---|---|---|---|---|---|
| | | Before. | After | | | |
| 5 | 17.052 | 18°.1 | 18°.6 | 8.08376 | 99996 | 99961 |
| 10 | 16.993 | 18.1 | 18.5 | 8.02677 | 98274 | 98242 |
| 20 | 16.888 | 18.1 | 18.3 | 7.92179 | 96938 | 96965 |
| 25 | 16.834 | 17.9 | 18.1 | 7.86779 | 96327 | 96296 |
| 30 | 16.775 | 17.8 | 18.0 | 7.80880 | 95605 | 95575 |
| 35 | 16.703 | 17.9 | 18.0 | 7.73681 | 94724 | 94794 |
| 40 | 16.625 | 17.7 | 17.7 | 7.65882 | 93769 | 93739 |
| 45 | 16.541 | 17.8 | 17.8 | 7.57484 | 92741 | 92719 |
| 50 | 16.456 | 17.4 | 17.5 | 7.48935 | 91700 | 91670 |
| 55 | 16.364 | 17.8 | 17.9 | 7.39786 | 90574 | 90544 |
| 60 | 16.272 | 17.7 | 17.7 | 7.30587 | 89447 | 89428 |
| 70 | 16.081 | 17.7 | 17.8 | 7.11490 | 87108 | 87080 |
| 80 | 15.885 | 17.7 | 17.7 | 6.91893 | 84710 | 84682 |
| 90 | 15.678 | 17.7 | 17.7 | 6.71196 | 82176 | 82149 |

The bottle in which these weighings were made was one imported from Germany, and of crown glass; in the reductions, I have employed for its coefficient of cubic dilatation 0.000027, nearly the mean of the data of MM. Lavoisier and Laplace.

145. The following weighings were made in the same manner, and with Duffey's balance, in a bottle of American flint glass, (specific gravity 3.1947,) which weighed alone 17.075 ounces troy, at the temperature 16°.3, being that of the room at the time of the weighings:

| Per cent. | Observed weight of bottle and liquid | Temperature. | | Reduced weight of liquid. | Apparent specific gravity. | Reduced specific gravity. |
|---|---|---|---|---|---|---|
| | | Before. | After. | | | |
| 0 | 47.000 | 15°.3 c. | 15°.4 | 29.9574 | 1.00009 | .99980 |
| 10 | 46.521 | 15.2 | 15.3 | 29.4785 | 98410 | 98382 |
| 20 | 46.154 | 15.1 | 15.2 | 29.1115 | 97185 | 97157 |
| 30 | 45.751 | 15.0 | 15.0 | 28.7036 | 95839 | 95812 |
| 40 | 45.217 | 15.0 | 15.0 | 28.1746 | 94057 | 94030 |
| 50 | 44.587 | 15.1 | 15.2 | 27.5147 | 91743 | 81717 |
| 60 | 43.923 | 14.9 | 15.0 | 26.8803 | 89738 | 89712 |
| 70 | 43.230 | 14.7 | 14.8 | 26.1830 | 87224 | 87199 |
| 80 | 42.509 | 15.0 | 14.8 | 25.4670 | 85018 | 84994 |
| 90 | 41.753 | 14.9 | 15.0 | 24.7111 | 82495 | 82472 |

In the reductions of the last column I have used the coefficient 0.000026, for the dilatation of the glass bottle, corresponding to 1° centigrade, which is nearly the mean of the results obtained by various observers, as will appear from the following determinations:

| | | | | |
|---|---|---|---|---|
| Lavoisier and Laplace, | French | flint | glass | 1.00087199 |
| " " | English | " | " | 1.00081166 |
| Smeaton, | " | " | " | 1.00083333 |
| General Roy, (a tube,) | " | " | " | 1.00077550 |
| " " (a solid rod,) | " | " | " | 1.00080833 |
| Dulong and Petit, | French | " | " | 1.00086133 |
| Despretz, | " | " | " | 1.00086000 |
| Magnus, | German | " | " | 1.00085156 |
| Regnault, (a tube,) | French | " | " | 1.00088266 |
| " (a globe,) | " | " | " | 1.00086400 |
| Mean | | | | 1.00084534 |

These numbers being the lengths which a piece of glass would have at the boiling point of water, if its length at 0°.C., or the freezing point, be assumed as unity, the mean value gives 0.00002636 for the coefficient of cubic dilatation.

146. To ascertain the specific gravities at different temperatures of the several specimens of absolute alcohol, furnished by Messrs. Powers and Weightman at successive times, and used by me in these experiments, a large brass hydrometer, having a bulb about five inches in diameter and seven inches in length, with a stem about one-tenth of an inch square, was employed. The object in using so large an instrument being rather to diminish the effect of slight and temporary causes of disturbance of temperature, &c., than to obtain more exact weighings. Indeed, for the latter purpose, a smaller hydrometer is probably to be preferred.

Whenever this instrument was used, the temperatures of successive horizontal stata of the liquor were carefully observed, and if they were found to differ, even a tenth of a degree, the whole mass was rendered uniform by repeatedly inverting the vessel with a rapid twitching motion, by which means perfect mixture was obtained. The same precautions with reference to temperature, which were observed with the small hydrometer, were also followed with this.

147. With specimen No. 1, this large hydrometer gave:

| Added weight. | Temperature. | | Reduced weight. | Apparent sp. gravity. | Reduced sp. gravity. |
|---|---|---|---|---|---|
| | Alcohol. | Room. | | | |
| 0.831 | 10°.7 C. | 10°.3 | 28.2136 | 799788 | 799494 |
| 0.839 | 10.6 | 10.2 | 28.2216 | 800013 | 799725 |
| 0.827 | 11.05 | 11.5 | 28.2096 | 799673 | 799364 |
| 0.822 | 11.3 | 11.6 | 28.2046 | 799531 | 799212 |
| 0.7945 | 12.2 | 12.2 | 28.1771 | 798752 | 798392 |

In the same alcohol, the alcoholometer of Tralles by Griener, indicated:

| Temp. | Per Cent. by Vol. | Correction. Attached Therm. |
|---|---|---|
| 10°.7 Cent. | 99.0 | — 2°. R. |
| 11 .3 " | 99.0 | — 1°.5 " |
| 12°.2 " | 99.0 | — 1 .25 " |

Each degree and a half of the *correction thermometer* being equivalent to one per cent by weight; hence the indicated strength was about 99.7 per cent. by volume for this specimen.

148. With specimen No. 2, and the same instrument, I obtained:

| Weight added. | Temperature. | | Reduced weight. | Apparent sp. gravity. | Reduced sp. gravity. |
|---|---|---|---|---|---|
| | Alcohol. | Room. | | | |
| 0.776 | 12°.8 | 13°.5 | 28.1581 | 798213 | 797826 |
| 0.557 | 20.6 (?) | 21.0 | 27.9396 | 792020 | 791288 |
| 0.7395 | 13.9 | 13.1 | 28.1221 | 797193 | 796753 |
| 0.5005 | 22.2 | 21.3 | 27.8831 | 790418 | 789617 |
| 0.701 | 15.0 | 14.1 | 28.0836 | 796102 | 795618 |
| 0.718 | 14.5 | 14.1 | 28.1006 | 796583 | 796121 |
| 0.720 | 14.4 | 14.1 | 28.1026 | 796640 | 796182 |
| 0.7205 | 14.4 | 14.1 | 28.1031 | 796655 | 796196 |

From this alcohol, specimen No. 2, the first series of standard mixtures, table XXXIII, § 123, were made. With it Tralles's alcoholometer indicated:

| Temp. | Per cent. by volume. | Thermometer of correction. |
|---|---|---|
| 20°.6 C. | 100.5 | + 1°.4 |
| 14 ·95 | 99.5 | — 0 .25 |
| 14 .4 | 99.33 | — 0 .5 |

It was, therefore, of an indicated strength of 99.6 per cent., nearly.

149. Similarly, another sample of the same alcohol, from a different vessel, gave:

| Weight added. | Temperature. | | Reduced weight. | Apparent sp. gravity. | Reduced sp. gravity. |
|---|---|---|---|---|---|
| | Alcohol. | Room. | | | |
| 0.701 | 15°.2 | 14°.1 | 28.0836 | 796102 | 795609 |
| 0.705 | 14.9 | 14.1 | 28.0876 | 796215 | 795734 |
| 0.712 | 14.75 | 14.1 | 28.0946 | 796414 | 795941 |
| 0.715 | 14.7 | 14.1 | 28.0976 | 796499 | 796028 |
| 0.521 | 21.3 | 21.0 | 27.9036 | 790999 | 790237 |
| 0.711 | 14.5 | 14.5 | 28.0936 | 796385 | 795923 |
| 0.671 | 16.0 | 16.3 | 28.0536 | 795251 | 794722 |
| 0.6465 | 16.9 | 17.0 | 28.0291 | 794556 | 7939[illegible]7 |
| 0.616 | 17.9 | 18.7 | 27.9986 | 793692 | 793[illegible]79 |
| 0.618 | 17.8 | 18.0 | 28.0006 | 793749 | 793141 |
| 0.694 | 15.4 | 15[illegible]5 | 28.0766 | 795903 | 795401 |

The second series of standard mixtures, table XXXIV., § 129, were made from this alcohol, and the last result was taken just before using it for that purpose.

150. A quantity of alcohol, of which the indicated strength was 95 per cent. by volume, according to Tralles's alcoholometer by Greiner, gave the following data, which serve to compare the dilatation of such liquor with that of absolute alcohol:

| Added weight. | Temp. of alcohol. | Reduced weight. | Apparent specific gravity. | Reduced specific gravity. |
|---|---|---|---|---|
| 1.320 | 17°.7 | 28.7025 | 0.813614 | 0.812995 |
| 1.449 | 12.7 | 28.8315 | .817271 | .816[illegible]80 |
| 1.615 | 6.8 | 28.9974 | 821974 | 821854 |
| 1.687 | 4.1 | 29.0694 | 824015 | 824020 |
| 1.730 | 2.1 | 29.1124 | 825234 | 825332 |
| 1.685 | 4.2 | 29.0674 | 823958 | 823958 |
| 1.688 | 4.1 | 29.0704 | 824043 | 824048 |
| 1.6215 | 6.6 | 29.0039 | 822158 | 822047 |
| 1.6275 | 6.05 | 29.0099 | 822328 | 822242 |
| 1.614 | 6.9 | 28.9964 | 821945 | 821829 |
| 1.630 | 6.15 | 29.0124 | 822399 | 822309 |
| 1.214 | 20.7 | 28.5925 | 810496 | 809742 |

Although the temperature of the room was not recorded, it was in every instance observed, and found not to differ materially from that of the alcohol.

151. To determine the specific gravities of the preceding experiments, from the observed weighings and temperatures, it was necessary to know the true or absolute weights of the hydrometers, and the weights which were required to sink them respectively in water at its maximum density.

The manner in which this was done for the large brass hydrometer was as follows: it was first weighed, with great care, upon the mint balance, and found to be *apparently* 27 3415 ounces troy, the temperature being 20° cent., and the *probable* height of the barometer 29.9 inches nearly. To the observed or apparent weight we must add, in order to reduce it to the true weight, the weight of the air displaced by the hydrometer, *minus* that of the air displaced by the weights in the opposite side of the balance.

The weight of the air displaced by the hydrometer itself was determined in the following manner: as the mean of six independent experiments, it appeared that at 4° 6 cent., the weight to be added to sink the hydrometer to its index point, amounted to 7.8954 ounces troy. Adding this to the observed weight of the instrument, we have 35 2369 ounces troy, for the apparent weight of the displaced water. For the correction to be applied, in consequence of atmospheric buoyancy exerted upon the stem, the dish and the added weights, the weight of the dish and that portion of the stem above the water was ascertained to be 0.75 ounces; adding this to the number 7.8954, we get 8.6454 as the quantity of brass exposed to the atmosphere. As the specific gravity of the metal, 8.472, is not *very* different from this number, we may, without appreciable error, regard their quotient, *or the volume*, as unity *nearly*, especially as it is to be multiplied by the small factor 0.0013, the ratio of the density of air to that of water. Hence, we have 0.0013 as the correction for atmospheric buoyancy, and 35.2356 as the corrected *apparent* weight of the displaced water. Multiplying this number by 0.0013, we have 0.04580628 for the weight of air at 0° cent., equal in volume to the displaced water. To this we must add 0.000975, the weight of air displaced by the stem and dish; and from it we must subtract 0.004199, the weight of the volume of air at zero displaced by the weights in the opposite scale pan of the balance; and we thus obtain 0.042582, which we must divide by the co-efficient 1.0734 of atmospheric dilatation to reduce it to the observed temperature 20° cent. This gives the value 0.03967 for the final result, or correction to be added to the *observed apparent* weight, 27 3415, we have, therefore, for the reduced or absolute weight of the instrument 27.3812 ounces troy.

152. In precisely the same manner, the reduced weight of the small brass hydrometer was obtained from the observed weight, 4.711 oz., at 18°.8, cent., and found to be equal to 4.7177 oz troy. The data of sections 130, 131, and coefficients of Despretz for the expansion of water, and of Lavoisier and Laplace for that of brass, being employed in the reduction required to obtain the weight of the instrument, and also that of itself and load, 6.0366 oz. troy, required to sink it to the index point in water of maximum density. By which number, therefore, all the weighings with this hydrometer are divided to obtain the corresponding specific gravities; proper corrections being first applied to them for atmospheric buoyancy, &c.

Also, similar calculations were made for a large glass hydrome-

ter, described below, (section 155,) by means of the data there given. The details of these calculations need not be enumerated, for they will present no difficulty to any one who shall reflect a little upon them.

153. With the view of multiplying observations as much as possible for water, especially at temperatures near to that of its maximum density, and of determining the coefficients of cubic dilatation for the large brass hydrometer, and one of similar size of flint glass, two sets of observations were made; the results of which are contained in the two following tables.

My reason for endeavoring to make as many observations as I could, at the temperature of maximum density, or rather at temperatures differing as little as possible from that degree, and also for referring the volumes of the hydrometers to the same temperature, was to ascertain, as exactly as practicable, the probable errors to which this method of taking specific gravities must be considered liable. If the volume of the hydrometer had been referred to the normal temperature of 0° cent., or 32° Fahrenheit, the corrections for dilatation would have been multiplied by larger factors, and their errors magnified.

TABLE XXXV.

*Densities of water, taken with the large brass hydrometer.*

| No. of exper't. | Weight added. | Temp. of water. | Temp. of room. | Reduced weight. | Apparent specific gravity. | Reduced specific gravity. |
|---|---|---|---|---|---|---|
| 1 | 7.897 | 4°.2 | 5°.0 | 35.2785 | 1.000043 | 1.000021 |
| 2 | 7.899 | 6.4 | 6.5 | 35.2805 | 1.000100 | 0.999955 |
| 3 | 7.895 | 4.5 | 5.7 | 35.2765 | 0.999938 | 0.999949 |
| 4 | 7.896 | 4.7 | 5.2 | 35.2775 | 1.000014 | 0.999964 |
| 5 | 7.896 | 4.8 | 5.2 | 35.2775 | 1.000014 | 0.999958 |
| 6 | 7.898 | 7.5 | 9.0 | 35.2795 | 1.000071 | 0.999869 |
| 7 | 7.897 | 6.7 | 6.6 | 35.2785 | 1.000043 | 0.999880 |
| 8 | 7.898 | 6.8 | 7.3 | 35.2795 | 1.000071 | 0.999902 |
| 9 | 7.898 | 7.3 | 7.8 | 35.2795 | 1.000071 | 0.999874 |
| 10 | 7.896 | 8.0 | 9.1 | 35.2775 | 1.000014 | 0.999788 |
| 11 | 7.897 | 10.3 | 10.5 | 35.2785 | 1.000043 | 0.999677 |
| 12 | 7.898 | 7.6 | 8.5 | 35.2795 | 1.000071 | 0.999858 |
| 13 | 7.898 | 9.0 | 8.5 | 35.2795 | 1.000071 | 0.999779 |
| 14 | 7.895 | 10.6 | 10.1 | 35.2765 | 0.999988 | 0.999606 |
| 15 | 7.8955 | 5.6 | 4.2 | 35.2770 | 0.999978 | 0.999910 |
| 16 | 7.886 | 2.0 | 4.7 | 35.2675 | 0.999731 | 0.999833 |
| 17 | 7.885 | 1.4 | 3.7 | 35.2665 | 0.999702 | 0.999838 |
| 18 | 7.894 | 4.2 | 4.9 | 35.2755 | 0.999958 | 0.999936 |
| 19 | 7.895 | 5.0 | 5.5 | 35.2765 | 0.999988 | 0.999921 |
| 20 | 7.8975 | 7.1 | 7.7 | 35.2790 | 1.000057 | 0.999872 |
| 21 | 7.898 | 8.8 | 9.2 | 35.2795 | 1.000071 | 0.999890 |
| 22 | 7.893 | 12.2 | 12.4 | 35.2745 | 0.999929 | 0.999456 |
| 23 | 7.890 | 13.5 | 13.0 | 35.2715 | 0.999830 | 0.999324 |
| 24 | 7.861 | 16.5 | 17.0 | 35.2425 | 0.999022 | 0.998307 |
| 25 | 7.857 | 17.0 | 17.0 | 35.2385 | 0.998908 | 0.998165 |
| 26 | 7.851 | 17.9 | 18.0 | 35.2325 | 0.998739 | 0.997945 |
| 27 | 7.826 | 23.2 | 23.0 | 35.2075 | 0.998030 | 0.996938 |

154. With the glass hydrometer the following similar results were obtained:

TABLE XXXVI.

*Densities of water, observed with a glass hydrometer.*

| No. of exper't. | Weight added. | Temp. of water. | Temp. of room. | Reduced weight. | Apparent specific gravity. | Reduced specific gravity. |
|---|---|---|---|---|---|---|
| 1 | 2.586 | 9°.0 | 10°.2 | 40.4311 | 1.000087 | 1.000075 |
| 2 | 2.580 | 10.3 | 10.4 | 40.4251 | 0.999938 | 0.999924 |
| 3 | 2.585 | 9.1 | 9.0 | 40.4301 | 1.000062 | 1.000050 |
| 4 | 2.581 | 10.6 | 10.1 | 40.4261 | 0.999963 | 0.999949 |
| 5 | 2.586 | 5.7 | 4.5 | 40.4311 | 1.000087 | 1.000084 |
| 6 | 2.580 | 2.0 | 4.5 | 40.4251 | 0.999938 | 0.999943 |
| 8 | 2.580 | 1.5 | 3.7 | 40.4251 | 0.999938 | 0.999944 |
| 8 | 2.582 | 4.2 | 4.9 | 40.4271 | 0.999987 | 0.999987 |
| 9 | 2.583 | 4.9 | 5.4 | 40.4281 | 1.000012 | 1.000010 |
| 10 | 2.585 | 7.1 | 7.7 | 40.4301 | 1.000062 | 1.000055 |
| 11 | 2.582 | 8.8 | 9.2 | 40.4271 | 0.999987 | 0.999976 |
| 12 | 2.573 | 12.3 | 12.4 | 40.4181 | 0.999765 | 0.999746 |
| 13 | 2.569 | 13.5 | 13.0 | 40.4141 | 0.999666 | 0.999644 |
| 14 | 2.554 | 16.7 | 17.0 | 40.3991 | 0.999294 | 0.999265 |
| 15 | 2.552 | 17.0 | 17.0 | 40.3971 | 0.999245 | 0.999214 |
| 16 | 2.547 | 17.8 | 18.0 | 40.3921 | 0.999122 | 0.999090 |

155. The apparent weight given for this hydrometer, when weighed with the mint balance, was 37.8025 oz. troy, at the temperature of 20° cent., nearly, and a *probable* barometric pressure of 29.9 inches. Its top above the index point was found to weigh 0.72 oz.; and, according to experiment No. 8, the weight required to sink it to that point in water of 4°.2 cent., is 2.582 oz. troy. From these data, with the coefficients used in other cases, (see sections 145, 151,) I deduced for its true weight, the value 37.8456 oz. troy; and for the reduced weight of the volume of water of maximum density which it displaces, 40.4276 oz.

156. It may here be stated, that in these experiments, 4°.2 cent. is always assumed to be the true temperature at which water attains its maximum density. This value being that which I obtained by the method of least squares,* from the observed data of M. Despretz. It is, therefore, the normal temperature to which all densities and volumes in the reductions are referred.

157. A mere inspection of the two tables just given is sufficient to show that this method of taking specific gravities, by means of hydrometers with weights, however delicate they may be made, and carefully the observations may be performed, is not to be relied upon beyond the fourth place of decimals, to which extent it seems to be exact. Thus, for instance, in TABLE XXXV., experiments

* See Sen. Doc. No. 165. Second session 28th Congress, p. 92; and above, see p. 99.

No. 1 and No. 18, were both made at the temperature 4°.C., that of maximum density; and should, therefore, have both given the specific gravity 1 000000; the probable error of the first result is, consequently, 0.000021, *plus*, and that of the second 0.000064, *minus*; and the range of error is 0.000085, or nearly unity in the fourth place of decimals.

Inaccurate as this method may, therefore, seem to be, I yet believe it to be far less so than that employed by Messrs. Gilpin and Blagden, when alcoholic liquors are to be examined. For it appears, by the observed data given in sections 144, 145, that from some cause which I could not readily detect, but supposed to be due to evaporation when the bottle is first filled, a difference of temperature occurs during the time of weighing, of one or two-tenths of a degree centigrade, which must give rise to errors of as many units in the fourth place of decimals. Nor could I obviate this difficulty, though I sought to do so in every way I could imagine.

I also attempted to use the method of weighing an immersed body. And, for this purpose, prepared two hollow glass globes of different sizes, which I loaded so that they should sink with feeble force in pure water; the weighings were made with Duffey's small balance, possessing all requisite sensibility and accuracy, but I could not obtain any satisfactory results. For alcohol, the oscillations were so slow that the temperature changed beyond all allowable limits during the weighing, producing currents in the liquid, and strata of different density and temperature. And even with water the experiments made at the same time were very contradictory. So that I was compelled to abandon this method altogether.

There is only one other method which would, I think, give results much more accurate than can be obtained by using hydrometers, which is that of thermometers made of the different liquids to be examined, by comparing the indications of which, the relative volumes, and consequently the densities, become known. This method I had hoped to have fully tested, but I was disappointed by reason of the ill health of the instrument maker, whom I had engaged to construct them; and I could not, in time for this report, find another person capable and willing to undertake, and properly execute, the work.

It was also my design to have discussed, by the method of curves, as well as by that of least squares, the data given in this chapter, with the view of eliminating all important errors. But for this task, which involves considerable labor, I have not yet had the necessary time.

## CHAPTER III.

*Per cents by volume and weight, and specific gravities corresponding to the indications of Dycas's hydrometer.*

158. Since by act of Congress the Secretary of the Treasury is authorized "to adopt and institute such hydrometer as he may deem best calculated to promote the public interest, in lieu of that now prescribed by law for ascertaining the proof of liquors, &c."; and since these researches were undertaken by request of the Treasury Department, because representations had been made that Dycas's hydrometer (the instrument now used in the revenue) is inaccurate, and it was, therefore, "deemed important to the interests of the revenue that a careful and thorough investigation of the subject should be had," it became necessary, not only to test the general accuracy of Dycas's hydrometer, which was done in the manner, and with the results already reported on a former occasion,* but also to furnish data which would enable the Secretary of the Treasury, in the exercise of the authority conferred upon him by law, to substitute another, and a more accurate instrument.

For this purpose, it is only requisite to ascertain with accuracy, what is the real per cent. by weight or volume, or in other words, the exact chemical composition of each of the several kinds of liquor which are classified in the laws of the United States, under the technical terms "*first proof*," "*second proof*," &c.; so that any other means which would attain the same end more correctly than those now employed, may be used instead of them.

159. In my former report I have traced the origin of these terms, and shown that they are in no way dependent upon, or connected with general commerce; but, on the contrary, that they are perfectly arbitrary, and derive their existence solely from the result of accident in the legislation of the Congress of the United States.† That they are employed, or even understood at all, by the dealers in spirits in our country, is simply due to the fact, that the duties are levied and paid in accordance with them. In other countries they are unmeaning words.

Hence it is evident, that not the least inconvenience or disadvantage can arise from the abandonment of a system which is so perfectly arbitrary and limited. It was created by our government for its own purposes; and, similarly, it should now be destroyed, that a more natural, simple, just and accurate system, may take its place.

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* Sen. Doc. No. 165, 23th Cong. 2d Sess., p. 100, and above see p. 108, 109.
† See Ibid. p. 96, and above see p. 104.

160. Although, in the report to which I have referred, I have given the definitions of the terms "*first proof*, *second proof*," &c., I may here repeat what I have therein stated, for the convenience of the reader. By act of Congress,* approved August 10, 1790, the hydrometer of Dycas is established as that to be used in the collection of the revenue, and spirits are divided into six classes, to wit: 1st, "distilled spirit of more than ten per cent. below proof, according to Dycas's hydrometer;" 2d, "if more than five, and not more than ten per cent. below proof, according to the same hydrometer;" 3d, "if of proof, and not more than five per cent. below proof, according to the same hydrometer;" 4th, "if above proof, but not exceeding twenty per cent., according to the same hydrometer;" 5th, "if of more than twenty, and not more than forty per cent. above proof, according to the same hydrometer;" 6th, "if more than forty per cent. above proof, according to the same hydrometer."

Why these perfectly arbitrary classifications, dependent upon a patented foreign instrument, based upon unknown private data, should have been made at first, it is now impossible to ascertain. But, by act of Congress, approved March 3, 1791,* they acquired *technical names*, which have since secured to them undisturbed existence, until they have become looked upon almost as natural and independent things, and not as creatures of legislative caprice. By that act, it is enacted "that the several kinds of proof shall be distinguished, corresponding with the order in which they are mentioned, by the words *first proof*, *second proof*, *third proof*, *fourth proof*, *fifth proof*, *sixth proof*;" and it is made "the duty of the Secretary of the Treasury to provide and furnish to the officers of inspection and of the customs proper instruments for ascertaining the said several proofs."

161. In future legislation, all reference to this arbitrary classification should be dispensed with; and the duties to be levied should be proportional to the per cent. by volume of alcohol in any liquor, except in cases for which the value depends rather upon some adventitious circumstances or peculiar flavor; but for temporary use, both by the government and by private persons, until it shall become well understood what per cent. of contained alcohol is equivalent to each of these "proofs," it was deemed expedient to determine experimentally, and with all possible care, the specific gravities and equivalent per cents. corresponding to the indications of Dycas's hydrometer.

162. One of the difficulties to be contended with arose from the want of a *standard* instrument, or any data based upon natural laws and facts. I had been furnished, it is true, with an instrument belonging to the Treasury Department, No. 1,019, made by Dycas; and also with several similar hydrometers, copied from

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* See Laws of the United States, vol. 2. p. 176. ch. 66. Sect. 1.
* Laws of the United States, vol. 2, p. 215, ch. 89, sec. 37.

those of Dycas, under the superintendence of Mr. Fisher, of Philadelphia. But as neither of these instruments could be considered as a true standard, to which all others might be referred, I of necessity felt much at a loss in the matter; the more so, because the instrument No. 1,019, which was the most authentic, had suffered slightly from indentations.

In the custom-houses of New York, Boston and Baltimore, I found three hydrometers in excellent order, used as standards at those several ports; and I, therefore, determined to adopt *the mean results* given by those three instruments, when compared with No. 1,019 of the Treasury Department, and with an alcoholometer of Gay Lussac, made by M. Collardeau, who alone is authorized to make them in France, and which I had imported for these researches. The following table contains the observed data of this experimental comparison:

| Per cent. by volume.-Gay Lussac. | Dycas's hydrometer. | | | |
|---|---|---|---|---|
| | U. S. Treasury Department. | Port of Boston. | Port of New York. | Port of Baltimore. |
| 92.0 | 325°.2 | 325°.6 | ..... | ..... |
| 87.8 | 296.5 | ..... | ..... | 296.6 |
| 84.5 | 276.9 | 277.3 | ..... | ..... |
| 84.5 | 276.2 | ..... | 276.3 | ..... |
| 82.8 | 266.7 | ..... | ..... | 266.5 |
| 80.3 | ..... | ..... | ..... | 254.0 |
| 79.7 | 249.6 | ..... | 249.5 | ..... |
| 76.0 | 229.4 | ..... | 229.7 | ..... |
| 75.0 | 223.8 | 224.2 | ..... | ..... |
| 73.2 | 215.3 | ..... | 215.0 | ..... |
| 72.9 | 214.2 | ..... | ..... | 214.0 |
| 69.4 | 197.8 | ..... | ..... | 198.2 |
| 66.5 | 183.1 | ..... | 183.0 | ..... |
| 64.3 | 174.0 | ..... | 173.9 | ..... |
| 64.2 | 173.0 | ..... | ..... | 172.6 |
| 62.0 | 164.3 | 164.7 | ..... | ..... |
| 59.7 | 154.8 | ..... | 154.8 | ..... |
| 59.8 | 154.0 | ..... | 154.0 | ..... |
| 55.5 | 137.8 | ..... | 137.3 | ..... |
| 55.0 | 135.5 | 135.7 | ..... | ..... |
| 53.0 | 127.5 | ..... | 127.0 | ..... |
| 50.3 | 118.8 | ..... | ..... | 118.6 |
| 50.3 | 118.7 | 119.4 | ..... | ..... |
| 47.6 | 109.7 | 110.5 | ..... | ..... |
| 45.5 | 102.8 | ..... | 103.3 | ..... |
| 43.7 | 97.7 | 97.3 | ..... | ..... |
| 41.6 | 90.3 | 90.5. | ..... | ..... |
| 34.8 | 72.8 | 72.7 | ..... | ..... |
| 30.5 | 64.3 | ..... | ..... | 64.0 |

163. From the data just given I constructed the following table, by interpolation, employing two methods—one graphic, by means of a curve drawn *among* the given points, to eliminate probable errors; and the other numerical, taking account of second differences:

TABLE XXXVII.

*Comparison of Gay Lussac's alcoholometer with that of Dycas.*

| Per cent. by volume of Gay Lussac. | Corresponding degrees of Dycas. | | |
|---|---|---|---|
| | By calculation. | Graphically | Mean. |
| 30 | 63°.3 | 63°.3 | 63°.3 |
| 35 | 73.2 | 73.2 | 73.2 |
| 40 | 84.7 | 85.5 | 85.1 |
| 45 | 101.1 | 101.2 | 101.15 |
| 50 | 118.0 | 118.0 | 118.0 |
| 55 | 135.5 | 135.5 | 135.5 |
| 60 | 155.2 | 154.7 | 155.0 |
| 65 | 178.0 | 175.5 | 176.7 |
| 70 | 199.5 | 199.4 | 199.5 |
| 75 | 224.0 | 224.0 | 224.0 |
| 80 | 251.5 | 250.4 | 251.0 |
| 85 | 279.8 | 278.7 | 279.2 |
| 90 | 311.0 | 311.0 | 311.0 |

164. According to Dycas's hydrometer, the following are the indicated degrees which correspond to the definitions of the different *proofs* given in the laws of the United States:

First proof, anything below 118° Dycas.
Second " from 118° to 128°.5 "
Third " " 128°.5 to 139° 75 "
Fourth " above 139.75 to 189°.0 "
Fifth " " 189 0 to 247.0 "
Sixth " " 247.0 indefinitely, "

For these values, the observed results of the table in § 162, give:

First proof, anything below 50 per cent. by volume.
Second " from 50 to 53 3 " "
Third " " 53.3 to 56 " "
Fourth " " 56 to 67.7 " "
Fifth " " 67.7 to 79.3 " "
Sixth " " 79.3 indefinitely, " "

165. With the first series of standard mixtures of table XXXIII., § 123, and two of the *secondary* series, § 128, the hydrometer of Dycas, No. 1,019, belonging to the Treasury, gave the indications of the annexed table:

| Per ct. of alcohol by weight. | Degree of Dycas. | Temp. Fahrenheit. | Per ct. of alcohol by weight. | Degree of Dycas. | Temp. Fahrenheit. |
|---|---|---|---|---|---|
| 5 | 18°.5 | 64°.6 | 60 | 190°.5 | 63°.3 |
| 10 | 31.0 | 63.5 | 70 | 235.0 | 64.0 |
| 20 | 53.0 | 63.5 | 80 | 283.0 | 63.5 |
| 30 | 77.5 | 63.5 | 85 | 307.0 | 62.7 |
| 40 | 109.5 | 64.0 | 90 | 335.0 | 63.5 |
| 50 | 148.0 | 65.2 | 100 | Sinks. | .... |

166. By means of the theory and mathematical formulas, given for Dycas's hydrometer in my former report,* and the following weighings by Mr. Saxton, of the office of weights and measures, made at my request, I have duduced the specific gravities which correspond to the indications of that instrument:

TABLE XXXVIII.

| Degree of Dycas. | Weight of the hydrometer and added load in grains. | Corresponding specific gravity. | Degree of Dycas. | Weight of the hydrometer and added load in grains. | Corresponding specific gravity. |
|---|---|---|---|---|---|
| 0 | 542.865 | 1.0000 | 190 | 485.665 | .8946 |
| 10 | 539.540 | .9939 | 210 | 479.883 | .8840 |
| 30 | 533.410 | .9826 | 230 | 474.305 | .8738 |
| 50 | 527.105 | .9710 | 250 | 468.718 | .8634 |
| 70 | 521.025 | .9598 | 270 | 463.290 | .8534 |
| 90 | 514.863 | .9484 | 290 | 457.850 | .8434 |
| 110 | 508.836 | .9373 | 310 | 452.505 | .8335 |
| 130 | 502.955 | .9265 | 330 | 447.040 | .8235 |
| 150 | 497.080 | .9157 | 350 | 441.495 | .8133 |
| 170 | 491.310 | .9050 | 360, or the bulb alone. | 437.565 | .8060 |

167. In a memoir of M. Francœur, on *Aréométrie*,† presented to the Academy of Sciences, of Paris, in 1842, a still more full series of weighings of the weights and bulb of one of Dycas's hydrometers are given. M. Francœur did not, however, compute the corresponding specific gravities; which I have, therefore, calculated and embodied in the following table:

* Sen. Doc No. 165, 2d session, 28th Congress, p. 80; and above see p. 86
† Mém. Sur l'Aréom. par M. Francœur.

TABLE XXXIX.

| Degrees of Dycas. | Weight in grammes. | Specific gravity. | Degrees of Dycas. | Weight in grammes. | Specific gravity. |
|---|---|---|---|---|---|
| 0 | 30.660 | 1.0000 | 190 | 27.449 | 0.8953 |
| 10 | 30.476 | .9940 | 200 | 27.292 | .8902 |
| 20 | 30.294 | .9881 | 210 | 27.135 | .8850 |
| 30 | 30.114 | .9822 | 220 | 26.981 | .8800 |
| 40 | 29.936 | .9764 | 230 | 26.818 | .8747 |
| 50 | 29.761 | .9707 | 240 | 26.656 | .8694 |
| 60 | 29.587 | .9650 | 250 | 26.497 | .8642 |
| 70 | 29.416 | .9594 | 260 | 26.339 | .8591 |
| 80 | 29.246 | .9539 | 270 | 26.184 | .8540 |
| 90 | 29.079 | .9484 | 280 | 26.030 | .8490 |
| 100 | 28.913 | .9430 | 290 | 25.883 | .8442 |
| 110 | 28.749 | .9377 | 300 | 25.718 | .8388 |
| 120 | 28.587 | .9324 | 310 | 25.565 | .8338 |
| 130 | 28.427 | .9272 | 320 | 25.414 | .8289 |
| 140 | 28.269 | .9220 | 330 | 25.264 | .8240 |
| 150 | 28.101 | .9165 | 340 | 25.121 | .8193 |
| 160 | 27.935 | .9111 | 350 | 24.980 | .8147 |
| 170 | 27.771 | .9058 | 360, or | 24.840 | .8102 |
| 180 | 27.610 | .9005 | the bulb alone. | | |

168. Of these two different tables, the results should be identical, if the instruments examined had been free from errors of workmanship. The corresponding specific gravities do not differ much for very dilute liquors; but for those of high degrees of strength, the variations amount to unity in the third place of decimals, or one-quarter of a per cent., by volume. The instrument examined by Mr. Saxton, was No. 671, by Fisher, and not an original authentic hydrometer made by Dycas himself, who *alone* knew the *secret* data employed for the proper manufacture of *his* hydrometers. For this reason, the results deduced from the weighings of M. Francœur are probably the most correct. I did not cause the hydrometer, No. 1019, by Dycas, belonging to the Treasury Department, to be compared in a similar manner, by weighing, with those from which these two tables are computed; but it may still be done, with but little labor.

169. It should be remarked, that neither the weighings of Mr. Saxton, table XXXVIII, nor those of M. Francœur, table XXXIX, are corrected for atmospheric bouyancy; the requisite data for such a correction not having been observed, or considered important. And that the specific gravities are not referred to water at its maximum density, but at 32° Fahrenheit, or the freezing point, which temperature was assumed by Dycas, as that for the origin of his scale. To reduce these specific gravities to the scale of water unity at 15° cent., adopted by Gay Lussac, we must multiply them by the constant factor 1.000074; and, similarly, for the corresponding values of the scale of water unity at its maximum density, we have the coefficient 0.999873; both of these coefficients being taken from the data of M. Despretz for the expansion of water.

170. With the latter of these multipliers and the weighings of M. Francœur, the following specific gravities have been calculated; to which are also annexed the equivalent per cents. by volume at 60° Fahrenheit, given by TABLE VII, of Tralles, in chapter I of this report:

TABLE XL.

| Degree of Dycas. | Specific gravity. | Per cent. by volume at 60° Fahr. | Degree of Dycas. | Specific gravity. | Per cent. by volume at 60° Fahr. |
|---|---|---|---|---|---|
| 0 | 0.9999 | 0.0 | 190 | 0.8952 | 67.5 |
| 10 | 0.9939 | 3.4 | 200 | 0.8901 | 69.6 |
| 20 | 0.9880 | 8.1 | 210 | 0.8849 | 71.7 |
| 30 | 0.9821 | 13.2 | 220 | 0.8799 | 73.7 |
| 40 | 0.9763 | 18.8 | 230 | 0.8746 | 75.7 |
| 50 | 0.9706 | 24.4 | 240 | 0.8693 | 77.7 |
| 60 | 0.9649 | 29.7 | 250 | 0.8641 | 79.7 |
| 70 | 0.9593 | 33.7 | 260 | 0.8590 | 81.6 |
| 80 | 0.9538 | 37.8 | 270 | 0.8539 | 83.7 |
| 90 | 0.9483 | 41.7 | 280 | 0.8489 | 85.0 |
| 100 | 0.9429 | 44.9 | 290 | 0.8441 | 86.5 |
| 110 | 0.9376 | 47.8 | 300 | 0.8387 | 88.3 |
| 120 | 0.9323 | 50.6 | 310 | 0.8337 | 90.2 |
| 130 | 0.9271 | 53.2 | 320 | 0.8287 | 91.3 |
| 140 | 0.9219 | 55.7 | 330 | 0.8239 | 92.7 |
| 150 | 0.9164 | 57.7 | 340 | 0.8192 | 93.9 |
| 160 | 0.9110 | 60.7 | 350 | 0.8146 | 95.3 |
| 170 | 0.9057 | 62.9 | 360 | 0.8101 | 96.5 |
| 180 | 0.9004 | 65.3 | ... | ..... | .... |

171. The above results will, it is believed, furnish all information which can be desired either by the government or by private persons, who may wish to know the equivalent values in per cent. of pure alcohol, for the arbitrary indications of Dycas's hydrometer; and will serve to let them readily accustom themselves to new terms which will come into use, if the government should abandon the old and faulty system heretofore employed.

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*An examination of the condition of the hydrometers in use by the revenue officers of several of the ports, and comparisons of some of those instruments, with others belonging to the Treasury Department.*

172. The instruments belonging to the Treasury Department, which I employed for the purpose of comparing those of the custom-houses, indirectly, with each other, in order to deduce the mean results given in §163, above, were five in number. *Two hydrometers of Dycas;* one made by Dycas himself, No. 1019; and the other by Fisher of Philadelphia, No. 671; the same for which the weighings of Mr. Saxton, §166, were made. (To distinguish

these hydrometers in the record of the experimental results, I shall simply call them *Dycas* and *Fisher*.) Also, *three alcoholometers of Gay Lussac*, which I shall call G. L. No. 1; G. L. No. 2; and G. L. No. 3. Of these, G. L. Nos. 1 and 2 were among the instruments in the office of weights and measures, collected by the late Mr. Hassler, and seem to be *standard* hydrometers, made by M. Collardeau, for they are of unusual delicacy and excellence of workmanship. The instrument G. L. No. 3 I imported from Paris; it was made by Collardeau, and is therefore authentic; but it is less delicate than the others. Its scale extends from 30 to 100 per cent., while those of G. L. Nos. 1 and 2 are much more limited. To have given to the stems of the latter sufficient length to include an equal number of degrees, would have rendered them too fragile.

173. *Baltimore.*—At this port I found two hydrometers.

"No. 5,841, made by Gammage, late Dycas, son in law, Liverpool," in excellent order. The standard of this port, and one of the three instruments referred to in §162, as those which I used for obtaining *standard* or mean results.

"No. 4,654, by Arstall, late Dycas, patentee, Liverpool." In constant use. Weights Nos. 260, 180 and 350 lost. Weight No. 30, of Dycas, No. 1,046, in the box of this instrument, a circumstance which might give rise to errors.

The thermometers belonging to these instruments were compared with one by Fisher of Philadelphia, with the following observed results:

| Fisher. | Gammage. | Arstall. |
|---|---|---|
| 48°.3 Fahr. | 47°.5 Fahr. | 46°.5 |
| 50.0 | 50.0 | 49.0 |
| 57.0 | 56.5 | 56.2 |
| 64.0 | —— | 63.5 |

In the thermometer by Arstall there was a considerable air-bubble.

*Comparison of the hydrometers.*

| Gamm. No. 5841. | Therm. | Arstædl. No. 4654. | Therm. | Dycas. | Therm. | Fisher. | Therm. | G. L. No. 1. | Therm. | G. L. No. 2. |
|---|---|---|---|---|---|---|---|---|---|---|
| 296.6 | 66.5 | 294.5 | 66.5 | 296.5 | 66.5 | 295.5 | 66.5 | 87.8 | 66.5 | 87.8 |
| 266.5 | 67.5 | Weight | gone. | 266.7 | 67.3 | 265.5 | 67.5 | 82.8 | 67.3 | 82.8 |
| 254.0 | 67.5 | 251.0 | 67.5 | ..... | .... | 252.0 | 67.5 | 80.3 | 67.5 | 80.3 |
| 214.0 | 69.0 | 212.0 | 69.3 | 214.2 | 69.2 | 213.3 | 69.2 | 72.8 | 69.2 | 73.0 |
| 198.2 | 69.0 | 195.5 | 69.3 | 197.8 | 69.5 | 196.8 | 69.5 | 69.4 | 69.5 | 69.4 |
| | | | | | | | | G. L. No. 2. | | |
| 172.6 | 69.5 | 170.6 | 70.0 | 173.0 | 70.0 | 172.0 | 70.0 | 64.2 | 70.0 | 64.0 |
| 154.8 | 68.0 | 153.5 | 68.0 | 154.8 | 68.0 | 153.6 | 68.0 | 59.7 | 68.0 | 59.7 |
| 118.6 | 71.0 | 116.0 | 70.7 | 118.8 | 70.0 | 117.5 | 70.4 | 50.3 | 70.0 | 50.5 |
| 103.3 | 71.0 | 100.3 | 71.0 | 102.8 | 71.0 | 101.6 | 71.0 | 45.6 | 71.0 | 45.5 |
| 64.0 | 72.2 | 62.2 | 72.0 | 64.3 | 72.0 | 62.7 | 72.0 | 30.5 | 72.0 | |

174. *Philadelphia.*—At this port the officers of the revenue had no standard hydrometer; Fisher's standard being resorted to by them for adjusting. There were in the marker's office four hydrometers.

"No. 336, by Fisher." That in use, and said to have been recently adjusted by Mr. Fisher. Several of the weights appeared new. The bulb indented, and weights Nos. 320, 340, 350 lost.

"No. 216, by Fisher & Son." Box locked and key lost; obtained a key to open it, and found the bulb in good order. The thermometer gone, also weights Nos. 330, 340, 350. This hydrometer not in use.

"No. 225, by Fisher." Also locked, and key lost. When opened, the weights were found complete, but the thermometer lost, and the bulb deeply indented. Good for nothing, and never used.

"No. 224, by Fisher." Also locked, and key lost. Bulb indented, weights 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 310, 320, and 350 gone. Appears to have been formerly much used.

The axis of the figure of No. 336, was curvilinear, so that the instrument, being unsymetrical, floated obliquely.

The following table contains the results of an experimental comparison of Nos. 336 and 216, with the hydrometers of the Treasury Department.

| Fisher. No. 336. | Therm. | Fisher. No. 216. | Therm. | Fisher. | Therm. | Dyoas. | Therm. | G. L. No. 1. | Therm. | G. L. No. 3. |
|---|---|---|---|---|---|---|---|---|---|---|
| 299.0 | 67.5 | 298.5 | 67.5 | 299.5 | 67.3 | 300.0 | 67.3 | 88.5 | 68.0 | 88.5 |
| 267.0 | 68.0 | 266.8 | 68.0 | 267.0 | 68.0 | 267.8 | 68.0 | 83.0 | 68.0 | 83.0 |
| 250.4 | 67.7 | 248.5 | 67.5 | 249.0 | 67.3 | 250.6 | 67.0 | 79.8 | 67.0 | 80.0 |
| 229.0 | 66.0 | 228.3 | 66.0 | 228.8 | 66.2 | 229.5 | 66.2 | 75.9 | 66.2 | 75.9 |
| 205.8 | 66.0 | 204.8 | 66.0 | 206.0 | 66.2 | 206.8 | 66.3 | 71.4 | 66.3 | 71.3 |
| | | | | | | | | G. L. No. 2. | | |
| 180.0 | 68.5 | 180.0 | 68.5 | 179.9 | 68.3 | 180.8 | 68.0 | 65.8 | 68.0 | 66.0 |
| 170.3 | 67.2 | 169.2 | 67.5 | 170.1 | 67.2 | 170.8 | 67.2 | 63.6 | 67.1 | 63.3 |
| 156.8 | 67.0 | 156.7 | 67.0 | 156.8 | 67.0 | 157.8 | 67.0 | 60.5 | 67.2 | 60.5 |
| 144.4 | 66.6 | 144.0 | 66.7 | 144.0 | 66.8 | 145.3 | 67.0 | 57.6 | 66.8 | 57.3 |
| 121.3 | 68.5 | 121.0 | 68.7 | 120.6 | 68.8 | 122.0 | 68.7 | 51.3 | 68.5 | 51.0 |
| 107.2 | 68.6 | 107.8 | 68.8 | 107.4 | 68.9 | 108.3 | 69.0 | 47.3 | 69.0 | 47.2 |

175. *New York.*—In the surveyor's office of this port, I found four hydrometers in use.

"No. 6342, by Gammage, late Dycas' patentee," the standard; marked "surveyor's test box, August, 1839." It appeared to be in *perfect* order. This is another of the three *standard* hydrometers referred to in section 162, from which I deduced mean data.

"No. 6338, by Gammage" Bulb indented and much worn; weight 160 lost and replaced by a new weight; weight No. 170 belongs to another instrument, and No. 340 is lost.

"No. 6341, by Gammage." Bulb slightly indented. Thermometer lost and replaced by one made by Fisher of Philadelphia.

"No. 6340, by Gammage." Bulb indented. Weights No. 270, 310, and 350 lost.

176. I was informed by the markers of this port, that they had never had occasion to prove spirits at temperatures below 32° Fahrenheit in winter, or above 80° Fahrenheit in summer. Under the tariff of 1842, their practice was to allow no liquor the benefit of drawback, as first proof, which should be more than ten per cent. below the proof mark of Dycas's hydrometer.

177. In proving spirits at this port, it has been customary to allow a deduction of one or two degrees from the indication of the hydrometer, for *instrumental errors*, if a liquor should happen to exceed by that amount the limit established by law for either of the several proofs. The reason assigned for this by the markers to myself, was a wish to be liberal to the importers. Their liberality has, however, been most certainly unjustifiable; for it will appear by inspection of the annexed table of comparative results, that the *standard hydrometer* of the surveyor's office, No. 6342, requires about *two* degrees to be added to the indications of the instruments in ordinary use to render them correct; also, that the standard hydrometer No. 1019 gives results very closely agreeing with those of No. 6342. Hence, it follows that whenever such a deduction of one or two degrees was allowed, a liquor was permitted to pay duty as of a lower degree of proof, which was in fact *three or four* degrees above the limit prescribed by law for that proof.

In no other port of those which I visited has a similar custom prevailed, except at New Haven, and it was adopted there in consequence of the advice of a former surveyor of the port of New York.

178. The following are the experimental data furnished by the above-mentioned instruments:

| No. 6342. | Ther. | No. 6338. | Ther. | No. 6341. | Ther. | No. 6340, | Ther. | Dycas. | Ther. | G. L. Nos. 1 and 2. | G. L. No. 3. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | | ° | | ° | | ° | | ° | | |
| 276.3 | 79.2 | 272.8 | 79.2 | 274.9 | 79.2 | ..... | .... | 276.2 | 79.0 | 84.5 | 84.5 |
| 249.5 | 79.6 | 245.7 | 79.5 | 247.7 | 79.5 | 247.4 | 79.5 | 249.6 | 79.5 | 79.7 | 79.7 |
| 229.7 | 80.0 | 226.0 | 80.0 | 228.0 | 80.0 | 228.0 | 80.0 | 229.4 | 80.0 | 75.9 | 76.0 |
| 215.0 | 80.0 | 213.5 | 80.0 | 214.0 | 80.0 | 214.0 | 79.5 | 215.3 | 79.0 | 73.2 | 73.2 |
| 197.0 | 80.0 | 193.6 | 80.0 | 195.5 | 80.0 | 195.6 | 80.0 | 197.2 | 80.0 | 69.5 | 69.3 |
| 183.0 | 80.0 | 182.0 | 80.0 | 181.6 | 80.0 | 181.2 | 80.0 | 183.1 | 80.0 | 66.5 | 66.5 |
| 173.9 | 79.0 | 172.1 | 79.0 | 172.3 | 79.0 | 171.5 | 79.0 | 174.0 | 79.0 | 64.2 | 64.3 |
| 154.0 | 80.2 | 153.4 | 80.2 | 153.5 | 80.3 | 153.6 | 80.5 | 154.0 | 80.3 | 59.8 | 59.7 |
| 137.2 | 81.0 | 136.2 | 81.0 | 136.7 | 81.0 | 137.7 | 80.9 | 137.8 | 81.0 | 55.5 | 55.4 |
| 127.0 | 81.0 | 126.2 | 81.0 | 126.1 | 81.0 | 127.5 | 81.0 | 127.5 | 81.0 | 53.0 | 52.5 |

179. *Boston.*—The instruments used by the revenue offices of this port were:

A standard hydrometer, "No. 3925, by Dycas," one of the three mentioned in section 162; which had been carefully preserved in the most perfect order, appearing, indeed, as if never used.

And "No. 4842, by Arstall, successor to Dycas;" the instrument in common use. Bulb deeply indented. Weights Nos. 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, and 360, not in the box, and mislaid or lost. Original thermometer brrken and replaced by one made by J. Slade, of Boston, which appears to be a very good one.

Results of comparison, as follows:

| Dycas No. 3925. | Ther. | Arstall. No. 4842. | Ther. | Fisher. | Ther. | Dycas. | Ther. | G. L. Nos. 1 and 2. | Ther. | G. L. No. 3. |
|---|---|---|---|---|---|---|---|---|---|---|
| 325.6 | 69.5 | No weight | .... | 323.3 | 69.7 | 325.2 | 69.5 | 92.0 | 69.5 | 92.0 |
| 277.3 | 72.0 | No weight | .... | 276.3 | 72.0 | 276.9 | 72.0 | 84.3 | 72.0 | 84.5 |
| 224.2 | 74.8 | 221.7 | 74.3 | 222.6 | 74.2 | 223.8 | 74.0 | 74.8 | 74.0 | 75.0 |
| 164.7 | 76.2 | 162.7 | 76.2 | 163.5 | 76.1 | 164.3 | 76.0 | .... | 76.0 | 62.0 |
| 135.7 | 77.0 | 134.2 | 77.0 | 134.3 | 77.0 | 135.5 | 77.0 | 55.0 | 75.8 | 54.8 |
| 119.4 | 76.5 | 117.3 | 76.2 | 118.0 | 76.1 | 118.7 | 76.0 | 50.4 | 75.8 | 50.3 |
| 110.5 | 76.2 | 107.7 | 76.2 | 108.5 | 76.0 | 109.7 | 76.0 | 47.7 | 75.8 | 47.6 |
| 97.3 | 76.0 | 95.2 | 76.0 | 95.5 | 76.0 | 97.7 | 76.0 | 44.0 | 76.0 | 43.7 |
| 90.5 | 75.7 | 88.6 | 75.3 | 89.0 | 75.3 | 90.3 | 75.3 | 41.6 | 75.3 | .... |
| 72.7 | 76.0 | 70.7 | 75.6 | 71.3 | 75.4 | 72.8 | 75.3 | 34.8 | 75.2 | .... |

180. *Portland.*—Two hydrometers here in use: "No. 4719, by Dycas," of which the bulb is slightly indented, weight No. 350 lost, and the thermometer broken; and "No. 5222, by Dycas," in perfect order.

At this port there is said to be very little trade in distilled spirits.

181. *Portsmouth, N. H.*—No hydrometer; only a fragment of a very old one in the custom-house. And no liquor either exported or imported.

182. *Newburyport.*—One very old hydrometer, in very good order for one so long in use. Without number, and unprovided at first with a thermometer. Also "No. 1069, by Dycas," entirely out of order, weights lost, bulb indented, and thermometer gone.

183. *Salem.*—A considerable quantity of domestic distilled spirits exported. The proof determined by a hydrometer of Tucker and Dwelle; purchased by a former surveyor; in good order, but not authorized by law.

The marker informed me that he has often proved rum at 22° Fahrenheit; and says that it frequently remains exposed on the wharf over night to be proved in the morning.

Here I also found "No. 1045, by Dycas," without a thermometer, and with its bulb so deeply indented that it is utterly worthless. And one very old hydrometer, without number, made by Dycas; many of its weights being lost; and no thermometer having been with it originally.

184. *New Bedford.*—No importation or exportation of spirits said to be done here. In the custom-house there is an antique hydrometer of Christopher Colles, New York, 1790, good for nothing. No gauging rods, etc.

185. *Bristol, R. I.*—No trade in spirits. One old worthless hydrometer in the office of the collector.

186. *Providence.*—In the custom-house I found hydrometer "No. 75, by Fisher," in good order, except that the thermometer was lost. Also another old specimen of a hydrometer, by Christopher Colles, of New York; to correct for temperature it has weights to be screwed on.

187. *Newport.*—"No. 5246, by Dycas;" in very good order, except that one weight and the thermometer had been lost.

188. *New Haven, Connecticut.*—Abundantly supplied with damaged hydrometers, namely:

"No. 2068, by Dycas," with its bulb indented. The thermometer having been broken and replaced by another.

"No. 2078," weight 350 lost, bulb indented; and the ivory scale empirically extended to 100° Fahrenheit.

"No. 9, by Dycas," no scale, no thermometer, and an indented bulb.

"No. 361, by Fisher," counterpoise broken off, bulb amalgamated by mercury, weight No. 150 lost.

189. From the preceding statements it will be evident that, with very few exceptions, I found the instruments now in the hands of the officers of the customs wholly unfit for use, by reason of accidental injuries which they have suffered. So that, generally, it would be impossible for them to determine with them the true strength of any liquor imported and subjected to their examination.

Respectfully submitted by your obedient servant,

RICHARD S. McCULLOH.

To Professor A. D. BACHE,

*Superintendent of Weights and Measures, &c.*

# AN APPENDIX,

SUPPLEMENTARY TO

# THE PRECEDING REPORTS ON SUGAR.

## NOTE A.

### IMPROVEMENTS IN OPTICAL CHEMISTRY.

During the time that the preceding investigations were in progress, M. T. Clerget, of Paris, was engaged in making an extended and valuable series of researches, having for their object the perfection of the optical method of analysing saccharine substances. And the celebrated optician, M. Soleil, of the same city, was also occupied in improving the polariscope or *saccharimeter*, as he has called it. I regret very much that the admirable labors of these gentlemen were simultaneous with and not prior to those of Mr. Reynolds and myself; for had they been performed a little sooner, they would have greatly aided us in the more exact and speedy execution of our work.

Their memoirs were presented to the "*Société d'encouragement pour l'industrie nationale*" of Paris, in October, 1846; and I am indebted to J. P. Benjamin, Esq., of New Orleans, for copies thereof, which M. Clerget did me the honor to send me, at his instance, and by his hand. For detailed information the reader may refer to the "*Bulletin de la Société d'encouragement*," and to an article by Mr. Benjamin, in De Bow's Commercial Review, vol. v., p. 357, April, 1848. The following reports of a committee of the Academy of Sciences, extracted from the *Comptes Rendus des Séances* of February, 1848, furnish a critical and correct abstract of the whole subject:

"REPORT ON THE SACCHARIMETER OF M. SOLEIL."

"(Commitee, MM. Arago, Regnault, and Babinet)."

"M. Soleil has presented to the academy three communications relative to the principles which have guided him in the construction of a *saccharimeter* adapted to the wants of the manufacturing industry. The first (see *Comptes Rendus*, 23d of June, 1845,) contains the description of a new mode of observing, by means of a double circular plate of rock crystal, of which the two semicircles are formed of plates of the same thickness, but of opposite rotations. The second (*Comptes Rendus*, August 18th, 1845) refers to a compensating prism of variable power, producing at will a rotation to the right or to the left. Lastly, the third (*Comptes Rendus*, May 31st, 1847) gives an account of an illuminator of variable tints, designed to permit the most suitable one to be employed; according to the nature of the light which traverses the saccharine solution, the degree of transparency or coloration thereof, and the individual disposition, permanent or accidental, of the eye of the observer."

"After the discovery of polarization by Malus, and that of chromatic polarization by M. Arago, which he observed in crystalline plates, in quartz cut perpendicularly to the axis, and even in uncrystallized bodies, such as various specimens of flint-glass, &c.,

M. Biot studied the phenomena of rotation of rock crystal traversed by polarized rays in the direction of the axis, and discovered that liquids and even vapors may possess rotary properties. Few scientific facts have excited so much astonishment as this action upon light, an action wholly independent of crystalline form, as well as of the consistence, whether solid, liquid, or gaseous, of the bodies which exert it. M. Biot ascertained that bodies retain their rotary powers without change of its direction, in solutions, in mixtures, and even in many chemical combinations; so that the rotation produced by the compound or mixture is in proportion to the quantity of the substance endowed with rotary power which it contains. He thus showed the molecular character of the action which he had discovered, and, at the same time, distinguished between it and the analogous action of quartz, which does not preserve this faculty in transparent silicious mixtures, which are either amorphous, hydrated, melted, dissolved in potash, or deposited in the vitreous state without crystallization. Lastly, he had the important idea of employing the rotating power of solutions in the chemical analysis of a compound, for the determination of the quantity of an active substance when combined with others of neutral character, by means of the optical effects it produces. Saccharine solutions attracted his attention more especially, by reason of the industrial importance of processes which make known the quantity of crystallizable sugar contained in a liquid more or less concentrated. M. Biot has set forth, in full detail, the precautions to be observed in measuring rotations with the utmost precision. He places his apparatus in a dark chamber; selects the white light of certain clouds in a particular state of the atmosphere; operates upon liquids sufficiently decolorized; measures the angular deviation of the plane of polarization of the polarized ray which has traversed the liquid; and has most happily selected a tint, which he justly calls *the sensible tint*, and which is such that the least deviation of the analyser in azimuth causes it to change rapidly; so that an observer, with a little practice, can readily seize this tint exactly and determine it with certainty, in the normal state of the eye when protected by darkness. To M. Biot is also due the important discovery that saccharine solutions follow the same laws as rock crystal, in their action upon the planes of polarization of rays of different colors; so that it is always possible to compensate the action of a certain thickness of a solution by that of a plate of rock crystal of suitable thickness and inverse rotation."

"It is upon this last property that M. Soleil has founded the measurement of the rotating power of a saccharine liquid—the chief object of his instrument. He substitutes for the graduated circle, a compensator formed of two prisms of rock crystal, cut perpendicularly to the axis, moveable one upon the other, and forming a plate of variable thickness, which, combined with a plate of constant thickness and inverse rotation, furnishes a neutral system for a normal position of the two prismatic laminæ. If, by a suitable sliding motion, the combined thickness of the two laminæ be increased, a resultant rotation is obtained in the direction of their

action, and proportional to the excess of the combined thickness of the two prisms over that of the invariable plate. If an inverse rotary effect is desired, the prisms are made to slide upon each other, so as to diminish their thickness, and the power of the invariable plate then predominant, will produce an excess of rotation in the direction proper to it, and proportional to its excess of thickness. According to the practical desiderata, the degree of precision required by the nature of saccharine solutions, and the fixedness of their action, M. Soleil has seen fit to graduate the scale to correspond to variations of hundredths of the millimetre in the the thickness of the quartz, which, by reason of the inclination of the prismatic laminæ, may be easily read off by a vernier, without a microscope. This quantity corresponds nearly to the quarter of a degree in deviation of the plane of polarization. The solution is contained in a tube, 20 centimetres long—the length which practice has indicated to be the most suitable. Liquids of even a considerable degree of color may be operated upon with them.* The rotating power of a liquid is, therefore, determined by the number of hundredths of a millimetre of quartz which compensates its action; and preliminary experiments, upon the compensation of known synthetic solutions, having made known the compensations corresponding to given proportions, reciprocally the proportions of solutions are deduced from the compensations required."

"The employment so advantageously made by M. Boit, of the clear violet blue, or *sensible tint*, (*fleur de lin*,) to obtain a certain and accurate mode of determination of rotating powers should be followed in every saccharmetric apparatus. M. Soleil has added to it an ingenious arrangement, which dispenses with the necessity of retaining that sensible tint in the memory; avoids the obligation of placing the eye in normal conditions, and, at the same time, does away with the fear of different judgments, dependent upon diversity of sight in observers."

"For this purpose he places in advance of the saccharine solution, and immediately behind the polarizer, a system composed of two juxtaposed plates of rock crystal of equal thicknesses, but of opposite rotations, which present two semicircular disks of different color as soon as the action of the liquid and that of the compensator cease to be equal; for then, the effect produced being added to that of one of the plates, and subtracted from that of the other, the double difference manifests itself immediately by a dissimilarity of tints in the two demi-disks. Multiplied experiments have shown that the action of laminæ of quartz, made as thin as possible, as well as that of very dilute solutions of sugar, can be observed and measured in this manner, with as much facility as that of rich solutions."

"When the plate of M. Soleil is of the thickness 3.75 millimetres, it gives, in the ordinary image of the two demi-disks, the sensible

* "According to M. Clerget, it is also for the purpose of avoiding homogeneous light, which does not answer well for the use of sensible tints, that deeply coloured liquids should not be employed."

tint of M. Biot; and, in the extraordinary, a yellow tint. With 7.50 millimetres, the sensible tint is in the extraordinary image, and the yellow tint in the ordinary. Either of these thicknesses may be employed. M. Soleil prefers the last."

"The double effect of diminution on one side, or in one of the semi-circular disks, and of augmentation on the other, shows the action of an active solution, by a difference of tints in the two demi-disks, which is always beyond mistake, because the two objects of comparison are presented together.* The advantages of this ingenious arrangement of M. Soleil, in a great number of cases, have been pointed out by M. Biot, (Mém. de l'Acad. t. XX, 1846; *Comptes Rendus*, t. XXI, page 452.) M. Arago, by substituting for the single plate of his polariscope, already so perfect, the double plate of M. Soleil, has obtained several important advantages, among others the determination of the plane of polarization, which is directed along the line of the centres of the two disks, when the two demi-disks are of the same tint, especially in the case of colored light, which causes some difficulty in the estimation of the direction of the plane of polarization, by means of that instrument. Also, in the instrument of Mr. Soleil, the constancy of particular indications, and the concordance of the results obtained by different observers, leave no doubt of the precision of the observations, especially when the *illuminator* is added, for the purpose of obtaining the most sensible tint which is adapted to each particular case."

"This third element of the apparatus of M. Soleil is designed to produce an illumination, such that, without decolorizing the liquid and with the employment at will either of daylight or the convenient light of a lamp, an observer may operate with a very sensible tint, selected according to the nature of the liquid and his own eye. M. Soleil at first made use of several colored glasses, which he placed in front of the apparatus, and by successive trials chose that which produced the tint which varied most rapidly with the motion of the compensator, and thus gave the greatest precision. The new illuminator, which gives readily a great number of different tints, without great loss of light, is simply a plate of rock crystal, about six millimitres thick, placed behind a Nicol's prism and in front of the polarizer of the apparatus. The polarizer developes in the polarized light, which thus reaches it through the plate of quartz, the ordinary colors; which, as is well known, offer a great variety of tints. To determine, among them all, that

* To show that, without the normal conditions, so exactly described by M. Biot, and necessary for certainty in observation, serious errors may be committed, M. Soleil has constructed an apparatus with a divided limb, furnished with a plate of quartz, giving the sensible tint. If in the open air, this tint be made to appear, by pointing to a portion of a moderately bright cloud, it will become red by pointing to a more illuminated part thereof, and blue when upon a more obscure portion. If, by moving the analyser, the sensible tint is reproduced, in each instance, great differences in the angles of deviation will be observed. In several experiments the difference amounted to four degrees. If the useful and indispensable precautions, recommended by M. Biot, are neglected, the blue of the sky, and other meteorological circumstances, may cause errors even of eight degrees.

which is most sensible, identity in the two demi-disks for any one of them is produced; and, if there is one more sensible than the rest, it will be that which, in a given position of the compensator, shows a difference in the demi-disks, while the others cause no perceptible dissimilarity. It is evident that the identity obtained for this tint subsists with greater force for all the others; and it is interesting to observe, how much the nature of this sensible tint varies for the particular liquid, light, and individual peculiarity of the eye, and how useful it is to be able to extend to any cases whatever the important practice of M. Biot."

"We have made several trials of the apparatus of M. Soleil, and particularly in the truly saccharimetric laboratory of M. Clerget. It would be too tedious to enumerate all the various contrivances and arrangements which have been invented to meet the wants which practice has indicated. The zero point, or origin of the scale of the compensator, is easily obtained, and the divisions by hundreths of a millimetre of quartz, which correspond to about fifteen minutes of deviation of the plane of polarization, each are sufficiently close.* The adjustment acquires a very great precision, by means of an eye piece analogous to a small Gulilean telescope; and the illuminator itself is followed by a collimator, which is very useful for the intensity of the light, and to prevent the injurious reflexions from surfaces behind the Nicol's prism, etc."

"With respect to the saccharimetric observations themselves, to which the instrument of M. Soleil is applicable with the greatest precision, and by means of which it has been several times improved in its arrangements; since these various processes are a very different thing from the instrument itself, of which they employ the indications, we will defer on account of them until we shall present a report on the labours of M. Clerget in relation to saccharimetry."

"In recapitulation, the instrument of M. Soleil is of convenient dimensions, and accurate indications; it gives by compensation exact measurements of the proportions of saccharine solutions, often without requiring them to be first decolorized; it permits a sensible tint to be easily chosen; it is adapted, both by day and by night, and in any place, to the use either of natural or artificial light, and also to the service of manufacturers; lastly, its indications always accord with themselves, and require no previous scientific knowledge in the person who makes use of it."

"Your committee, therefore, propose to you that you bestow approbation upon the saccharimeter of M. Soleil, and that you order the notes, relative to the compensation, the illumination by

* "The programme of a prize offered by the *Société d' encouragement* called for a process which will determine, *within two per cent.*, the richness of saccharine substances. The saccharimeter of M. Soleil is much more exact. It should not be forgotten that the instrument is a saccharimeter, or an industrial instrument of sufficient precision for the purposes for which it was designed. For scientific inquiries of a different order, M. Biot has remarked, that it would be necessary to modify it in several of its arrangements, to render it susceptible of verification by the observer himself, in order to give it a length adapted to different researches, and to suit it to homogeneous light. These modifications have already been partially executed by M. Soliel, by means of several purely scientific contrivances.

variable tints, and mode of observing by means of similar tints in two demi-disks of inverse rotations, together with the drawings of the instrument, and the details of its construction, to be published in the *Recueil des Savants etrangers.*"

"The conclusions of this report were adopted."

"REPORT ON THE SACCHARIMETRIC RESEARCHES OF M. CLERGET."

"(Committee, MM. Arago, Regnault, and Babinet.)"

"The importance of *saccharimetry*, or of the determination of the quantity of crystallizable sugar, ($C^{24}$, $H^{22}$, $O^{11}$, Dumas,) contained in a given solution, is placed beyond doubt by the avidity with which industrial persons, both agriculturists and refiners, have sought after M. Biot's optical instruments, by means of which that indispensable object may be attained, at any moment in the course of the operations of their factories. M. Biot, after having originated this curious branch of industrial optics, announced that he would not go beyond the strict wants of science, to devote himself to the less rigorous exigencies of manufacturers. He left to artists the responsibility of determining what degree of exactness should be given to ordinary saccharimetric apparatus; and they could avail themselves of the numerous results, which M. Biot had deduced from his labors in relation to the tint to be chosen, the amount and direction of the rotation, the inversion by acids, the laws of compensations, &c. The academy has already given its approbation to the saccharimeter of M. Soleil, designed especially for industrial purposes. The labors of M. Clerget, who employs that instrument, have for their object to render exact all the precautions which must be taken, as well as the manipulations and apparatus to be used, in order to ascertain with certainty the proportion of sugar in a saccharine liquid, which has been extracted from a crude substance, then defecated, rapidly subjected to inversion, and measured in graduated vessels of convenient capacity. For this purpose he has constructed a table, which dispenses with all calculations, and makes known the proportions of sugar directly; the influence of temperature upon the rotary power of the sugar which has been inverted being taken into account.

"The mechanical contrivances of M. Clerget, which we exhibit to the academy, are, (independently of the saccharimeter of M. Soleil,)

"1st. A metallic extractive press, of a power equal to that of cane mills, which serves for experiments upon various parts of vegetable substances.

"2d. Graduated vessels for defecation and filtration. After numerous experiments, M. Clerget has fixed upon fish glue and alcohol as the agents for obtaining a complete defecation, and a ready filtration.

"3d. Various tubes and measures, for decolorization by means of animal charcoal. In this connexion M. Clerget has made the important discovery that the first portions of a saccharine liquid which pass through bone black are weaker than those which pass

subsequently, the latter alone retaining their primitive strength. A graduated vessel shows the quantity of the liquid which should be excluded at first, in order to obtain the real title."

"M. Clerget has also ascertained that, in some cases, and particularly in the analysis of brown sugars, the double operation of defecation and decolorization is advantageously obtained by means of subacetate of lead; the powerful action of which upon coloring matters is well known."

"4th. Several graduated vessels with a thermometer, for performing inversion by acids. By elevating the temperature to 68° centigrade, by means of a spirit lamp, and employing concentrated hydrochloric acid, as M. Biot had done, in quantity sufficient to increase the volume of the solution one-tenth, M. Clerget obtains a complete and certain inversion in less than fifteen minutes."

"It is known that this curious property of inversion in the direction of the rotary power, so well rendered useful by M. Biot, belongs exclusively to cane sugar, ($C^{24}$ $H^{22}$ $O^{22}$,) which is extracted also from several other plants; and that it serves to determine the quantity of that sugar contained in any mixture whatever. Mr. Mitscherlich first found that temperature exerts a considerable influence upon the rotary power of cane sugar after inversion. M. Clerget, who had independently observed the same influence, studied it with the greatest care; he spared neither time nor pains to obtain its ratio; and the result of his labor is an extended table for determining, at any temperature, the saccharimetric title, from a knowledge of the number of divisions indicated by the saccharimeter, before and after inversion."

"Lastly, various measures graduated by volumes of 50 and 100 cubic centimetres, or more, and in equal divisions. In each measure a quantity of crystallized rock candy is dissolved, sufficient to cause the saccharimeter to indicate 100 divisions. M. Clerget finds that 16.471 grammes of sugar is requisite for 100 cubic centimetres."

"The following is, in few words, the mode of obtaining a measure. The above mentioned normal liquid is put into the tube of the saccharimeter, 20 centimetres long. It marks 100 divisions, when the color of the two demi-disks is brought to identity. The inversion is performed, and 30 divisions, for example, are observed in the opposite direction, at the temperature of the experiment. Hence, a range of 130 divisions is produced by the given proportion of sugar. If now, another solution be examined and found to give 80 divisions to the right, and then, after inversion, 10 divisions to the left, we have a range of 90 divisions; and the ratio of 90 to 130 will be that of the quantity of sugar contained in the second solution to the quantity contained in the first; the proportion of sugar in a solution under examination may thus be determined. But the table of which we have spoken dispenses with the necessity of this calculation; it gives at once the strength of the solution observed before and after inversion, corresponding to the indications of the saccharimeter and the degree of the thermometer.

"To arrive at precise results, and to furnish instruments of cer-

tain and ready manipulation, M. Clerget has evinced a patience and dexterity which have surmounted all difficulties. The measurement of the action of the temperatures upon the coefficient of inversion alone required situations of invariable temperatures, extended media to avoid the influence of surrounding bodies, and repeated observations to establish the constancy of the effects. Lastly, his whole system of manipulations has been brought to the point that, for a long time, a practical trial, not less enlightened than assiduous, has found in it nothing to change."

"This report being confined to saccharimetry itself, we will abstain from mentioning the numerous results obtained by M. Clerget, comprising the analysis of a great number of vegetable saccharíferous substances, the assaying of brown sugars, either alone or mixed together, the more intelligent management of the processes of manufacture; lastly, the study of the influence of different modes of culture upon the saccharine richness of the products."

"The academy being called upon to judge of the merit of applications of scientific principles of general utility, will regard with favor the persevering and conscientious researches of M. Clerget, which, without doubt, are of a nature to facilitate the progress of industry, by furnishing it with a complete optical saccharimeter. The politico-economical questions relative to the production of domestic and colonial sugar, to the rates of impost, and to the interests of navigation and commerce, add much more to the value of the determinations which may be accomplished by means of the saccharimetric processes of M. Clerget."

"Your committee recommend that you bestow your approbation upon the researches and instruments of M. Clerget; and that you order the communications which he has made to the institute, as well as the table of strengths of saccharine solutions, determined with regard to the temperature, together with exact diagrams, upon a scale of sufficient size, of all the apparatus he employs, to be published in the *Recueil des Savants Etrangers*."

"The conclusions of this report were adopted."

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## NOTE B.

### ANALYSES BY MM. CLERGET, CASASECA, AND PELIGOT.

The following analysis, by M. Clerget, extracted from the memoir above mentioned, (*Bull. de la Societe d'encouragement*, 1846, p. 552,) is in accordance with those given by myself in articles 12, 13, and 17 of my third report:

"A portion of an Otaheite cane, cultivated in the West Indies, weighing 200 grammes, was subjected to the action of the press, and left a pulp weighing 48 grammes. It yielded, therefore, 152 grammes (76 p. ct.) of juice, of which the specific gravity was 1.085 at 15° centigrade; and this juice, observed by means of the saccharimeter, caused a deviation to the right of 124° of the ver-

nier. Now, by multiplying this number of degrees by 16.471, and dividing the product by 10, we find the quantity of sugar per litre of juice to be 204.24 gr., and such is in fact the number found in the table corresponding to the indication 124°; also, the following proportion, 1085 (weight of the litre) : 204.24 (weight of the sugar) : : 1 : $x$, giving for $x$ the value 0.1882, shows that this juice contained 18.82 per cent. of sugar. Lastly, by multiplying 0.1882 by 152 gr., the weight of the expressed juice, we obtain the total amount of sugar contained in the juice which 200 gr. of the cane yielded by pressure alone, 28.6 gr., or 14.3 per cent. of the weight of the cane."

In the *Ann. de Chim. et de Phys.*, t. xi., p. 39, to which I have refered in article 13, Mr. Casaseca, professor of chemistry in the university of Havana, gives the following analysis and criticisms upon those of M. Péligot. He obtained from creole cane juice, of the density 11° Baumé at 33° centigrade, by evaporation and washing with hot alcohol of the density 38° Baumé, 21.2 per cent. of dry solid matter. Also 100 grammes yielded, by incineration, 0.14 ashes; and 200 grammes gave, with subacetate of lead, a precipitate which lost 0.24 of organic matter. Hence Mr. Casaseca deduces the composition:

| | |
|---|---|
| Water | 78.80 |
| Sugar | 20.94 |
| Ashes | 0.14 |
| Organic matter | 0.12 |
| | 100.00 |

M. Péligot obtained for Otaheite cane juice, from Martinique, 21.3 per cent. of solid matter. Also, "170 cubic centimetres of this juice, of the density 1.088, left 0.32 gr. of white silicious ashes, analogous to those produced by the incineration of the graminea. In a second experiment, 300 c. c. left 0.55 of ashes, which gives 0.17 for 100 of juice." From these data, M. Péligot *erroneously* stated the composition of the cane juice to be 20.9 sugar, 77.17 water, 1.7 mineral salts, and 0.23 organic matter. This error M. Casaseca attributes to inadvertancy, and corrects by giving the following composition as the result of M. Péligot's analysis:

| | |
|---|---|
| Water | 78.70 |
| Sugar | 20.90 |
| Ashes | 0.17 |
| Organic matter | 0.23 |
| | 100.00 |

From the close accordance between these proportions and those of his own analysis, Mr. Casaseca argues that soil and climate cause cane juice to vary only in the quantity of water it contains, the

saline and other impurities being only *thousandths*, and, therefore, inconsiderable in quantity or importance.

Mr. Casaseca also dried 920 grammes of creole cane, for 12 hours, at the temperature of boiling water, after which it weighed 313.5 gr.; having therefor lost 606.5 gr. of water by evaporation. Hence he deduces:

| | |
|---|---|
| Water | 65.9 |
| Add sugar | 17.7 |
| Juice | 83.6 |
| Woody fibre | 16.4 |
| | 100.0 |

This result accords very closely with that which I have given in article 22 of my third report, and it does not differ much from the analysis of the same variety of cane mentioned in article 8 of the same report. It, however, differs very considerably from the results obtained by M. Péligot, which are contained in his memoir on the composition of the sugar cane of Martinique, and in his report to Admiral Duperré on the manufacture of sugar and the composition of the sugar cane. I extract from M. Boussingault's Rural Economy the following table, containing the condensed results of M. Péligot's experiments:

| | Water. | Sugar. | Woody fibre. |
|---|---|---|---|
| First shoots, (plant canes) | 73.9 | 17.2 | 8.9 |
| Second shoots, or first rattoons | 71.7 | 17.8 | 10.5 |
| Third shoots, or second rattoons | 71.6 | 16.4 | 12.0 |
| Fourth shoots, or third rattoons | 73.0 | 16.8 | 10.2 |
| Knots of the cane | 70.8 | 12.0 | 17.2 |
| Cane of eight months | 73.9 | 18.2 | 7.9 |
| Cane of ten months | 72.3 | 18.5 | 9.2 |
| Inferior part of the cane | 73.7 | 15.5 | 10.8 |
| Middle part of the cane | 72.6 | 16.5 | 10.9 |
| Upper part of the cane | 72.8 | 15.5 | 11.7 |

As Mr. Casaseca and myself agree in making the proportion of woody fibre, contained in the creole or crystalline cane of the island of Cuba, equal to 16 per cent. nearly, there can be little doubt of the probability of this result. The question naturally arises, therefore, how can this fact be reconciled with those contained in the above table compiled from M. Péligot's report? In the first

place, I will state that Mr. Casaseca's paper was unknown to me at the time when I was engaged in the experiments made by me in Cuba; our results are, therefore, entirely independent. I may also state that M. Péligot's report had not been previously seen by me; I had ordered it from France, but did not receive it before my third report was printed and published. Secondly, while I forbear to claim for my own results, though confirmed by those of Mr. Casaseca, that full degree of confidence to which they would be entitled, if not discordant with those of M. Péligot, I venture to offer the following criticisms as reasons why, in my opinion, M. Péligot's conclusions may be erroneous.

In his memoir on the composition of the cane of Martinique, pages 28 and 29, M. Péligot states that the dried cane when received by him was partially decomposed; that he could no longer obtain from it crystallizable sugar only; yet, from these *fermented* canes, ("évidemment altérées") he has deduced (see page 26) the composition of *fresh* Otaheite cane, in the following manner:

"M. Gradis obtained for me, from Martinique, several kilogrammes of cane, dried in a furnace at 60°. According to a note sent to me by him, M. Peraud had obtained from 24 kilogrammes of fresh cane 7½ kilogrammes of dried cane. They, therefore, contained 68.7 per cent. of water. But their desiccation was not complete; for, by exposing them," (after they reached Paris, and when "évidemment altérées") "to the temperature of 100° cent., they lost 9 or 10 per cent. more of water. From which data, the composition of the fresh cane should be 72 per cent. of water and 28 per cent. of solid matter."

Now, how can we know that this loss of "9 or 10 per cent. more" was due to desiccation alone? Or rather, when fermentation has once taken place in an organic substance of so complicated a nature as dried sugar cane, what connexion has the fact, that it will then lose 9 or 10 per cent. by drying in a stove at 100° cent., with its composition when fresh and unaltered? These remarks are not made in disparagement of the value of M. Péligot's researches, still less in censure of himself. If he has erred, he will be one of the first to admit the error, and his reputation rests upon too solid a foundation to be affected by any trifling mistake which he may have committed.

As M. Péligot followed the same method in his experiments upon the specimens sent to him from Guadaloupe by M. Dupuy, it may not be uninteresting to construct from the data furnished by the memoranda of M. Dupuy, and given by M. Péligot in his report, another table showing the results of the drying performed in the island, by exposing the pieces of cane for 24 hours to the temperature of 60° to 80° centigrade, previously to putting them in bottles for exportation. M. Dupuy thus obtained—

| | Water. | Dry matter. | Juice. | Woody fibre. |
|---|---|---|---|---|
| From plant canes, 1st shoots..... | 73 | 27 | 88.33 | 11.67 |
| From 1st rattoons, 2d shoots..... | 71 | 29 | 85.91 | 14.19 |
| From 2d rattoons, 3d shoots..... | 71 | 29 | 85.91 | 14.19 |
| From 3d rattoons, 4th shoots..... | 70.7 | 29.3 | 85.55 | 14.45 |
| Knots ..... | 70.6 | 29.4 | 85 43 | 14.57 |
| Cane of eight months..... | 71.4 | 28.6 | 86.39 | 13.61 |
| Cane of ten months..... | 71 | 29 | 85.91 | 14.19 |
| Inferior part of the cane..... | 71.2 | 28.8 | 86.15 | 13.85 |
| Middle part of the cane..... | 71.4 | 28.6 | 86.39 | 13.61 |
| Superior part of the cane ..... | 71.8 | 28.2 | 86.88 | 13.12 |

These results accord with those obtained by me in Cuba, (see arts. 6, 9, 21, and 23 of my third report,) and render it evident that the *apparent* discordance between M. Péligot's analyses and those of Mr. Casaseca and myself, is due solely to the circumstance of his having added to the water evaporated in the island the loss sustained by the canes when subjected, in Paris, to the temperature of 212° Fahrenheit, and when, in all probability, their composition had suffered change by fermentation.

In De Bow's Commercial Review, of July, 1848, Mr. Avequin, of New Orleans, who had sought to determine the composition of the cane, and obtained results similar to those arrived at by M. Péligot, has attributed extreme negligence to me, by reason of the discordance which I have just discussed. The reader may refer to his article, and to the reply thereto, in the October number.

Although I differ from M. Péligot in some of the minor conclusions of his most excellent report to M. Duperré, I yet agree with him in very many of the views which he has adopted, and so ably exposed and recommended. That report was known to me, when I submitted the results of my own work, only through accounts and reviews of it in the writings of others. Had it been within my reach, I should have extracted much from it which I was compelled to obtain at second hand; and I now take pleasure in giving to the reader entire a translation of it, with the remark that it is one of the most frequently quoted and valuable documents ever written in relation to the sugar industry.

NOTE C.

*A report to Admiral Duperrè, minister of the navy and colonies, relative to the manufacture of sugar and the composition of the sugar cane. By M. E. Pèligot, professor of chemistry, &c., &c.*

PARIS, *June* 17, 1842.

SIR: In consequence of the work which I published in November, 1839, on *the chemical composition of the sugar cane of Martinique*, you were pleased to charge M. Dupuy, pharmaceutist of the first class of the navy, with a special mission, having for its object the performance, at Guadaloupe, of a series of new experiments relative to the composition of the cane, and the transmission to France of specimens, designed to permit me to continue the researches which I had commenced concerning that plant.

I submitted to you in December, 1839, the instructions which you did me the honor to request me to draw up, and which I prepared in concert with M. de Jabrun, then delegate from Guadaloupe, for the guidance of M. Dupuy, pharmaceutist, &c., in the selection, preparation, and transmission of the various substances. Those instructions contained succinct directions for the labors to which he should devote himself upon the spot; for the purpose of completing the information previously acquired in relation to the composition of the cane, and the quantity of sugar extracted from it in Guadaloupe.

M. Dupuy, pharmaceutist of the navy, has performed his mission with zeal and ability. I received, in October, 1840, from M. le Baron Roussin, minister at that time, the products of the cane sent by M. Dupuy; they were accompanied by a preliminary report, which treated of their origin, of their preparation, and of the mean yield or product of the sugar industry in Guadaloupe; I likewise received, on the 7th of April, 1841, through the minister of commerce, the second report sent from Guadaloupe by M. Dupuy, in continuation of his first report; lastly, the minister of commerce, submitted to me, on the 13th of December, 1841, the third report which M. Dupuy transmitted in the month of September last, and which contains useful information concerning experiments tried in relation to the desiccation of the cane, and the extraction of the sugar from dried cane, as a manufacturing operation.

Conformably to the request which you made of me, I shall now present to you a condensed analysis of the three reports of M. Dupuy. I will discuss the results presented in them, indicating the matters which seem to me of the most interest; and I shall introduce, in this discussion, the experiments which I have made upon the products confided to me for examination, as well as those which have been performed by other chemists since the publication of my first essay.

I will also reply to various questions, and to some criticisms, addressed to me upon the occasion of my first analyses; and, in short, I shall endeavor to throw light, derived from the numerous documents which we now possess, upon these two points, the most

important in the manufacture of sugar; the quantity of sugar extracted from the cane, and that which might be obtained by improved methods.

*First part of the report of M. Dupuy.*

In his introductory remarks, M. Dupuy, pharmaceutist of the navy, after giving the botanical description of the sugar cane, enumerates all the services rendered to man by that plant, which, besides the sugar and molasses, so useful for his nourishment, furnishes, in its woody fibre, a valuable fuel; in its leaves, a manure; in its top, when green, abundant food for cattle; and, when dry, covering for the dwellings of the negroes and for the begassa houses. He states that in Guadaloupe the Otaheite cane is almost the only variety which is planted, and that this large and robust variety succeeds equally well in low moist soils, and upon the dry slopes of the more or less elevated districts of the colony. But, adds M. Dupuy, within the period of fifty years, during which it has been cultivated and propagated by cuttings in the West Indies, it has considerably degenerated; orders have, therefore, been given, that the plant be renewed by fresh importations from the fertile plains of the island of Otaheite.

Is this degeneration of the cane in the West Indies real? Some experienced colonists, among whom is M. Jollimont de Marcelles, of Martinique, doubt its truth; while many others admit it, by reason of the circumstance that nobody denies the fact that the extraction of sugar was formerly more easy and more abundant than at present; so that it seems to be agreed that either the cane, or the manufacture of sugar, has degenerated in our colonies within the last fifty years.

There would be, in any event, much interest in comparative analyses of canes cultivated in Otaheite and those which may first grow in our colonies from plants brought from that island; if those analyses were made with exactness, we might hereafter, by repeating them, follow step by step the decline of the cane, and explain it, perhaps, by comparing the climates and soils of the two localities.

M. Dupuy, attaching a just importance to the quantity of saccharine juice which is extracted from the cane, and which varies with the greater or less degree of pressure produced by the cylinders between which the canes are crushed, describes minutely the experiments which he has made to establish the yield in juice, on the numerous plantations which he visited.

Those experiments were made under the ordinary circumstances of manufacture, and upon quantities of cane which varied between 100 and 6,000 kilogrammes; the canes, being weighed, were passed through the mill, and by measuring the juice obtained, or by weighing the dried begassa, and sometimes by employing both processes, the quantity of juice produced was obtained.

By summing up these experiments, which were made in the different communes of Guadaloupe, to wit, in the communes of Basse

Terre, Trois Rivières, de la Capesterre, de la Baie Mahault, de l'Anse Bertrand, du Port Louis, du Morne à l'Eau, des Abymes, de Sáinte Aune et du Moule, M. Dupuy has established the fact that the average extraction of juice, obtained by passing the canes once through the mill, as is always done in practice, furnishes the following mean comparative results:

| | | | |
|---|---|---|---|
| 61.8 | per cent. | of juice, by | hydraulic mills. |
| 61.2 | do | do | those with horizontal rolls. |
| 60.9 | do | do | steam mills. |
| 59.3 | do | do | water and wind mills. |
| 59.2 | do | do | mills with vertical cylinders. |
| 58.2 | do | do | mills of animal power. |
| 56.4 | do | do | wind mills, which are still employed to some extent in Guadaloupe. |

These numbers give the result of 44 trials, performed with 17 water mills, 15 wind mills, 7 mills with horizontal cylinders, and 5 steam mills. The mills in operation in Guadaloupe amount to 600 nearly.

In discussing this yield, and assuming 59.3 as the mean result, furnished by the kind of mills which are most numerous, M. Dupuy remarks that the loss, which amounts to one-third of the whole quantity of juice contained in the cane, might easily be diminished by mills of better and more solid construction. He observes, at the same time, that, in the mode of working usually followed, the manufacturer seems to appreciate the necessity of a great pressure less because he is interested in the begassa, which he wishes to economize and not to break too much, because it is the only fuel which he employs for his crop. Nevertheless, M. Dupuy estimates that, if the pressure usually exerted by the mills were to produce 65 to 66 per cent. of juice, the most desirable point would be attained, both with reference to the management of the begassa and the increased yield in juice.

In fact this difference of 59 to 65 per cent. of juice is sufficient, as the calculations of M. Dupuy show, to produce an excess of 14,000 kilogrammes (28 hogsheads) of sugar on a plantation producing annually 200 hogsheads of 500 kilogrammes each. Now, these 14,000 kilogrammes, at 250 francs per 500 kilogrammes, are worth 7,000 francs, without taking into account the value of the molasses. The whole crop of the island, which is 70,000 hogsheads, would be increased in value to the extent of 1,837,500 francs, independently of the molasses. This increase would also take place without additional expense.

These results are sufficiently certain to demand the grave consideration of the colonists. Their importance is such that, by reason of the limits established by the daily work, the fortune or ruin of a planter must depend more upon the greater or less degree of pressure of his canes than upon any other cause.

Nothing is more contradictory, moreover, than the documents upon this question, so important in the sugar industry, namely, the yield in juice of the cane.

I have cited, in my first memoir, some experiments made at New Orleans by Mr. Avequin, a skilful pharmaceutist, which establish that the yield of canes is 50 per cent of juice in that locality.*

M. Senez, of Cayenne, obtained, by means of a mill moved by a steam engine of eight-horse power, 36 per cent. of juice from canes.

M. Dupuy has shown that, at Guadaloupe, the yield varies from 68.5 to 54 per cent. The mean of the results obtained by M. Dupuy is 56 per cent.

M. Guignod (a citizen of Martinique, who has published, in the annals of the agricultural society of that colony, several articles which contain criticisms, sometimes just, but always bitter and intemperate, upon my first essay in relation to the cane,) obtained, by a single pressure, 63 per cent., and by a second 7 per cent. of juice, which makes 70 per cent. of juice obtained from canes.

M. Guignod, who is certainly an experienced and skilful manufacturer, disputes the accuracy of the yield stated by M. Senez; but, as he rests solely upon conjectures, and upon the difference of incomplete results obtained at Cayenne and on his own estate, his opinion upon this point has no great value. He thinks that the mill which gave him the above mentioned 70 per cent., is inferior to nine-tenths of those of Martinique; and he estimates at 76 per cent. of the weight of the canes the juice which several of the best established mills of the colony can furnish by a first and second pressure.

It is also known that on almost all of the plantations the canes are rolled but once. A quantity of juice is thus constantly lost, which varies from 4 to 7 per cent. of the weight of the canes, and which would be obtained by means of a second pressure. In fact it is customary in Martinique to pass through the mill at the same time, with fresh canes, the begassa furnished by a first pressure; but this method cannot, in any manner, increase the yield of juice, since the begassa, being moistened, as at first, by the juice which flows from the fresh canes, should absorb, at the moment when

---

* The following results of five experiments in Louisiana, "made upon the plantation of Mr. V. B. Marmillion, 25th November, 1842, with a first rate horizontal mill, moved by a steam engine of 16-horse power," are published by Mr. Avequin in De Bow's Review, vol. VI., No. 1, page 31, 1848:

| Variety. | Juice expressed. | Begassa. | Density of juice. (Baumé) |
|---|---|---|---|
| Ribbon canes | 63.1 | 36.9 | 8°.25 |
| Violet do | 63.0 | 37.0 | 8.5 |
| Gray do | 64.0 | 36.0 | 7.75 |
| Otaheite do | 65.8 | 34.2 | 8.5 |
| Creole do | 67.8 | 32.3 | 9.0 |

Mr. Avequin adds: "I could mention other experiments made for the same purpose in other mills, which experiments have clearly demonstrated that a large number of planters in Louisiana obtain from 63 to 64 per cent. of juice."—(*Note by the translator.*)

they escape from the action of the cylinders which compress them, all the juice which their spongy tissue can imbibe in resuming its size by dilatation.

Lastly: M. Paul Daubrée, in a remarkable essay, published in 1841, having for its title—*Question coloniale sous le rapport industriel*, thus remarks: "Having checked this estimate (that of M. Dupuy) upon some badly furnished plantations, the number of which is considerable, we are convinced that the mean yield is, in fact, only 50 per cent.; five-tenths, therefore, only are obtained, and four-tenths remain in the woody portion, commonly called begassa."

Whatever may be the actual yield, it is evident that the most essential part of the colonial work, the extraction of the juice, leaves at this moment much to be desired. Can this extraction be improved? Every body is agreed upon this question, and some mills already furnish a yield much beyond that generally obtained.

It is essential to insist upon this point, that the treatment of the cane, in order to extract from it the greatest amount of juice, may be performed by several different methods. We will point them out succinctly.

1st. The most direct will always consist in employing powerful mills, producing at first the largest proportion of juice, which proportion may be practically estimated at 70 per cent. of the weight of the canes, and 76 by a second pressure.

But the precarious state in which the colonial industry has long found itself, places it in the power of but few planters to procure mills of better construction, often also requiring greater motive power. This process is, therefore, of very limited availability at present.

2d. The addition of a fourth cylinder to these mills of better construction, or even to the mills in use, should be very useful; it accomplishes the effect of producing this second pressure immediately, without retarding the work, and thereby increases the proportion of juice from 4 to 7 per cent. M. Guignod himself advises this addition, strongly opposed as he is to experimental improvements, which he considers useless—the colonists working, in his opinion, as well as possible.

By causing a fine stream of water to fall upon the begassa at the moment when it is subjected to this second pressure, the operation would be rendered still more effectual.

3d. In my memoir on the analysis of the cane, I have stated that, by immersing the begassa in water and then rolling it a second time, the yield would be greatly augmented. This method seems to be that which is the best adapted to the mills of three cylinders now in use, when they cannot exert sufficient pressure.

Supposing the quantity of water absorbed by the begassa to be equal to the quantity of juice which it has already given, we see that it will furnish by this maceration a liquid containing one-half as much sugar as the original juice; so that, if the juice expressed at first indicates 10 degrees Baumé, the new liquid will mark 5 degrees of the same instrument.

If, now, the pressure exerted upon this washed begassa furnishes

a quantity of liquid equal to that already obtained, 56 per cent., for example, the two extracted liquids together would afford 112 of juice, marking 7½ degrees, Baumé; so that, if the quantity of saccharine liquid, supposed of equal density, is represented by 56 in the first treatment, it will become 79, by means of this washing.

Observations made on the spot by M. Dupuy show that each gallon (4 litres) of juice, marking 9 degrees, Baumé, weighs 1 kilog. 90 gr., and furnishes 500 gr. of sugar, (being 21.8 per cent.;) whence it follows, that instead of obtaining 7.1 per cent. of sugar, the colónist, by aid of this second operation, would get 10 per cent.

Applying this calculation to a plantation which produces 100,000 kilog. of sugar, (200 hogsheads,) which would give a gross return of 50,000 francs, the receipts, in consequence of this new yield, will become 70,536 francs.

The practical difficulties and the expenses of this operation remain to be discussed.

The begassa subjected twice to the action of the mill will probably be found to be too much divided to render it practicable to employ it for fuel, in the manner usually followed. But because the employment of this fuel will offer, at first, some difficulties to be overcome, should so important an augmentation be renounced? Perhaps, in the spirit of despondency which has seized upon many of the colonists, some will reply affirmatively to this question; but all the friends of progress, all those who believe that improvements introduced into a branch of industry conspire, above all things, to its preservation and prosperity, will seek to know and surmount those difficulties.

The state of division of the begassa will, as we have said, render the handling of the fuel more difficult, and at the same time will hinder it from burning in the present furnaces, in the same manner as when it has kept the primitive form of the cane.

It is easy to put the begassa thus torn asunder into a more compact form. In Martinique, this operation is already performed in some cases by tying together the more divided portions.

But this fuel will become insufficient to evaporate the excess of water which the new process would require. That is probable, although it is also possible that, by a more extended arrangement in the fire places, the begassa may suffice for the evaporation.

Admitting that in fact the use of some other fuel may become necessary, let us examine whether its price would render this operation impracticable.

In Martinique, the country being densely wooded in the uncultivated portions, wood now costs but little more than the expense of cutting and hauling to the plantations. This difficulty does not, therefore, exist for that colony; it exists still less, by reason of the fact, that if the use of wood became general the present expense of transportation would be probably diminished by making roads and keeping them in better order, as a matter of general utility.

But in Guadaloupe and the other colonies, I suppose they would

be obliged to import coal from England, Belgium, or France, and that this fuel would cost the high price of 5 francs per hectolitre. Since one kilogramme of coal evaporates at least five of water, and one hectolitre of coal weighs about 80 kilogrammes, we find by calculation, (supposing the juice to indicate 7½°, Baumé, and to contain 15 per cent. of dissolved matter, sugar and molasses, and that these two substances are obtained in the ratio of 3 to 1,) that one kilogramme of coal will furnish one kilogramme of sugar, which would consequently cost 6 c. for fuel, or 6,000 francs for 100,000 kilogrammes of sugar.

Now, we have seen above that the quantity of sugar would become equal to 141,000 kilogrammes by reason of the new yield. The expense for coal would, therefore, be 8,460 francs.

But as this expense is based upon the whole of the manufacture, while the begassa should, as usual, serve to evaporate at least half of the water contained in the 112 of juice, it is proper to reduce the required quantity of coal to one-half of the above.

Hence, 141,000 kilogrammes of sugar would cause an increased expense of 4,230 francs, and, as the 141,000 kilogrammes are worth the additional sum of 20,536 francs, the advantage arising from this operation would be 16,306 francs.

In these calculations I have neglected the molasses and the value which it represents.

The operation of washing and second pressure, which I here discuss, is not a mere chimera, or which amounts to the same thing with many persons, a theoretical operation; for M. Dupuy says in his report that, on the plantation of M. Jabrun, he has extracted, on a large scale, one-fifth more of sugar than is obtained by the ordinary method, by means of washing and rolling the fresh begassa, without changing the usual work of the sugar-house, or tearing the begassa so much as to unfit it for fuel. It is to be regretted that M. Dupuy has not given a detailed account of the trials which he made of this method.

4th. Lastly, it is probable that the peculiar system of extraction of beet sugar, which is due to M. de Dombasle, and which is known as *the process of maceration*, might be advantageously applied to the cane. It is known that this accomplished agriculturist has long pursued, with a degree of perseverance and confidence now justified by his success, the application of a method which permits a quantity of sugar, incontestably greater than that obtained by the ordinary methods, to be extracted from the beet. For this method furnishes, according to its author, the whole of the sugar which exists in that plant.

The introduction of this process in the colonial industry would produce the following immediate consequences:

1st. The abandonment of mills, rendered useless as the presses are in the extraction of beet sugar by maceration.

2d. The acquisition of nearly all the saccharine juice in the cane.

It is evident that, "if to these advantages we add the practicable improvements in the treatment of the juice, for the extraction of

the sugar, improvements which we will discuss hereafter, the manufacture of cane sugar would promptly attain a degree of perfection which could not be surpassed, and from which at present it is far removed.

It is known that the process of maceration reposes upon the principle long admitted and employed of systematic washings, (*"lavages methodiques;"*) for the description of which process I refer to one of the numerous publications of M. de Dombasle. In my opinion, it is applicable, with some modifications, to the manufacture of cane sugar.

The cutting of the canes, by which we commence, is an easy operation. The tissue of the plant being formed of transverse fibres and very permeable to water, the mixture of its saccharine juice with the water added will take place promptly.

For the beet, maceration is performed with hot water in the first kettle, and completed by subsequent washings with cold water; for the cane, the continued use of hot water would probably be indispensable. It is only within a few years that M. Mathieu de Dombasle has substituted for the hot water used in all the macerations immersions in cold water; it was necessary to do so in order to realize a condition indispensable to his system, economy of fuel; but in my opinion, it has not been demonstrated that this modification is as advantageous as he believes it to be; it is certain that in some factories which employ his method the work does not proceed well, except when intermittent; that, when it is continuous, the sirups refuse to crystallize after a certain number of turns (*virements*,) as if some portions of the fermentable matter of the beet which the temperature of 100°, (212° Fahrenheit,) should destroy, were, nevertheless, regenerated in the cold water vats, and had transformed the sugar into a substance incapable of crystalizing.

Since the fermentation of saccharine juices is the more active in proportion as their temperature approaches 30° to 40° centigrade (85° to 100° Fahrenheit,) since in the colonies the ordinary atmospheric temperature would produce that degree of heat nearly, and since it is known, that as soon as fermentation takes place the crystallizable sugar is in part destroyed, it would very probably, be necessary to keep the liquids during the whole series of macerations, at a temperature sufficiently elevated to prevent fermentation from occurring or continuing.

5th. Finally, the desiccation of the cane in stoves, or by the sun, and the subsequent treatment of the dried residue, either in France or upon the spot, might be employed perhaps with advantage. At the end of this report I will discuss this method, which will furnish, if well managed, a much greater quantity of sugar than that produced in the ordinary way.

These different systems may, therefore, lead to a greater yield of sugar than that now obtained. In pointing them out, I have not the folly to suppose their execution exempt from difficulty; but I believe that they are worthy of trial and of comparative examination, and that their discussion may give rise to improvements which are urgently needed. It is time that the colonists should believe

that there are several methods of extracting sugar from the cane; that it is not impossible to carry their industry out of the beaten track which they have so long followed; that routine is good only when it protects and preserves processes which science (another name merely for knowledge and good sense) indicates as the best; that indifference to progress in manufactures is not allowable, even, when rivalry and coöperation are wanting.

The first report, of which the above is an analysis, accompanied the boxes filled with the products of the sugar cane, which were entrusted to me for examination; it ends with an inventory of the substances which M. Dupuy has collected.

In discussing the second part of M. Dupuy's report, I will give an account of the experiments which I have made with those products.

*Second part of the report of M. Dupuy.*

This second part, which was transmitted to me on the 7th of April, 1841, by the minister of agriculture and commerce, contains documents of interest, alike in reference to the composition of the cane, both fresh and dried, to the processes of manufacture followed in Guadaloupe, and to the useful modifications of those which could be immediately introduced.

M. Dupuy repeated on the spot the experiments which I have published, upon the composition of the cane and the non-existence of uncrystallizable sugar in that plant. Those experiments have been, both in France and Martinique, the subject of active dispute; some have questioned their accuracy—others their novelty. My first attempts, having been performed with insufficient materials, should, in fact, afford room for criticisms; of which I would not complain, though they have been sometimes unjust and in ill temper, for those criticisms have provoked new researches and contributed to the discovery of truth.

By following simple processes of analysis, which should apparently furnish exact results, M. Dupuy has found that canes of which the density marks 10½ degrees Baumé, at the temperature of 28° centigrade, leave, by desiccation at 100° centigrade, twenty-eight per cent. of solid residue; they, therefore, contain seventy-two of water.

The treatment of one portion of this residue with water, and the incineration of another portion, in order to obtain the fixed salts which it contained, led M. Dupuy to assign to the canes which he analyzed the following composition:

| | |
|---|---|
| Water | 72.0 |
| Woody fibre | 9.8 |
| Soluble matter | 17.8 |
| Salts | 0.4 |
| | 100.0 |

This composition is very closely accordant with that which I have deduced from the examination of the juice and the dried canes which I received from Martinique in 1839—since I found:

| | |
|---|---|
| Water | 72.1 |
| Woody fibre | 9.9 |
| Soluble matter | 18.0 |
| | 100.0 |

This analysis needed very much to be carefully checked, since it was obtained by indirect means from the composition of the juice on the one hand, and on the other from that of the canes dried on the spot—with all requisite care, it is true, for the skill and experience of M. Péraud are guarantee thereof; but, nevertheless, without my participation.

I think that it may now be admitted as a well established fact, that the insoluble substance, or woody fibre, which constitutes the solid fabric of the cane, exists in it in the mean proportion of 9 to 11 per cent.; I speak only of mature canes, fit for working.

This conclusion, however, does not seem to accord with the results obtained in Martinique, by M. Guignod, assisted by several members of the agricultural society of that colony; for M. Guignod found that 150 kilogrammes of canes furnished 18.5 kilogrammes of begassa, after they had been passed through the mill, then washed with water to extract all the sugar; and, lastly, subjected to desiccation; so that, according to this result, 100 of canes contain 13 of woody fibre.

But it is very probable that this discrepancy is only apparent; for M. Guignod does not say whether his washed begassa was dried by the atmosphere, or in a stove at the temperature of 100° centigrade; and it is, therefore, probable that he performed this desiccation at the ordinary temperature of the air; now, however long a substance so porous as begassa may be subjected to continued contact with the air, even under the influence of the rays of the sun, it will always retain several per cent. of water, which the temperature of 100° can alone remove; so that if, in fact, M. Guignod produced the desiccation by means of the air alone, the results which he has published do not invalidate those which have been obtained by M. Dupuy and myself; which also accord with experiments made in 1825 by M. Avequin, an apothecary of New Orleans.

Nevertheless, notwithstanding this concordance between analyses made under very different circumstances, I have seen fit to avail myself of the specimens collected and prepared at Guadaloupe by M. Dupuy, to ascertain the composition of the cane by means of new experiments.

These specimens which M. Dupuy collected and prepared with great care, are of several sorts; they respond to the *desiderata* enumerated in the instructions, drawn up by M. de Jabrun and myself, to guide M. Dupuy in his mission; and they consist principally of,

1st. Juice of different origin, preserved by the method of Appert;

2d. Dried cane;

3d. Fresh canes.

To each of the specimens is attached a number engraved on a disc of lead; which correspond to the same number in the inventory of substances, at the end of the first part of the report of M. Dupuy; its source, the circumstances of its growth, etc., are there also stated

As was to have been expected, these specimens were not all in an equally good state of preservation. While that of the dried canes left nothing to be desired, it was not so with the juice; of which most of the bottles had become quite sour, and had a taste at the same time vinous and pricked, indicating fermentation more or less complete. This juice was assuredly very different from that which I analysed in 1840; which was, and is even now, (I still have a bottle of it,) in a state of perfect preservation.

This difference is, without doubt, independent of Appert's method; which was employed in both instances, and which also assures the indefinite preservation of substances much more alterable than cane juice; I think that it was due chiefly to the manner in which the bottles, sent by M. Dupuy, were corked; most of them had corks which were too small and of bad quality; they were removed by the slightest force; moreover, the wax around them was brittle and in part detached before the arrival of the bottles. It is known that the method of Appert is effectual only as long as the substances placed under its protection are kept without any subsequent contact with the air.

This alteration of the juice sent from Guadaloupe is greatly to be regretted; it prevents the realization of the project I had of studying, attentively, the substances foreign to the sugar which exist in cane juice; in very small quantities, it is true, but still sufficient, perhaps, to have some influence upon the yield, when they accumulate in the residues and in the molasses. The examination and separation of those substances, (of the albuminous matter in particular,) is possible only when a sufficiently large quantity of juice can be obtained. This condition was fulfilled, for I received thirty litres of that liquid; but its bad state of preservation rendered the examination impracticable, without probably confounding the pre-existing substances in the juice of the plant with those produced by its spontaneous alteration. This confusion is not always easy to avoid when we operate upon a normal liquid; and it is impossible to eliminate it from one already altered.

As some of the bottles were untouched, I was enabled to employ them usefully, as will appear, to aid in solving some questions which I have purposed to decide.

The fresh canes were of different ages and different *rattooning;* sealed with wax at the ends immediately after having been cut; then packed in layers with dry sand, in a case of zinc, the cover of which was soldered on. This soldering, in fact, was rendered useless by reason of a large hole made in one of the sides, probably by the revenue officers, habitual destroyers of scientific specimens.

The good preservation of these canes, with all their water of

vegetation, was not anticipated; but the attempt was deemed worthy of trial, whatever the result might be. It did not succeed; the canes were profoundly altered; but even the circumstances of their alteration are attended with interest.

These canes, analysed immediately after the opening of the zinc box, furnished a large quantity of juice by means of a slight pressure.

The liquid was somewhat viscid, of a clear yellow, of a fresh sweet taste and an odour like that of apples. Subjected to evaporation, pure or defecated, it did not yield any crystals of sugar, even after a considerable lapse of time; alcohol separated from it a somewhat abundant viscous matter.

I dried some pieces of these canes; the dried residue varied from 20 to 24 per cent. of their weight. This proportion is less than that of canes in their ordinary or fresh state, since in these the residue amounts to 28 per cent.; as it is not probable that they could have absorbed water from dried sand and in a box of metal, it must be admitted that they suffered a change quite peculiar; their sugar being in part transformed into volatile or gaseous elements, without passing into the vinous fermentation; for the neutrality of their juice proves that carbonic acid, alcohol and acetic acid, were not formed at the expense of the saccharine liquid.

It is necessary that future researches upon this kind of alteration, so important to be thoroughly investigated, and so little understood, should teach us whether, contrary to what we now believe, the products which remain after viscous fermentation are of less weight than that of the sugar which has been destroyed.

Lastly, a dozen bottles contained dried cane; the excellent state of preservation of which left nothing to be desired, and of which I made good use.

Besides these principal objects, the boxes contained specimens of the soils in which the canes sent had grown; specimens of the sugar produced by the juice; and, lastly, a specimen of ferruginous sand, which exists in large quantity at l'Anse-Saint-Sauveur.

I will now set forth the results of the experiments which I have made with these different products:

The most important question to be settled is, certainly, that which concerns the original state of the sugar in the cane; some details in regard to the position of this question seem to me useful to be given.

Chemists have admitted until recently, that the sugar which exists in the cane, and in the beet, is partly in the state of crystallizable sugar, and partly in that of liquid or uncrystallizable sugar; it is sugar, in the latter state, which constitutes the sirup or molasses, which is always produced in the manufacture of sugar, from those plants.

Accurate experiments having shown some years ago, that in the beet all the sugar pre-exists in the crystallizable state, it was probable, that it was so likewise with the cane. Yet, all the chemists who had occupied themselves with that plant had, on the contrary, concluded that a quantity more or less

considerable of liquid sugar pre-exists therein. Thus Cazaux, in a book published fifty years ago, admits that the most usual proportion, *as well as the most desirable*, between the sugar and the molasses in canes, is equality in weight of those two substances. Dutrone Lacouture, whose work, though published in 1790, is still followed as authority by some of the colonists, not only refrains from doubting the pre-existence of the molasses, but even gives tables to show the proportions by means of the density, in which it is mixed with the sugar. More recently, an illustrious French chemist, Proust, arrived at the same conclusion, by means of an analysis of canes from Malaga. Lastly, M. Avequin, a skilful pharmaceutist of New Orleans, published in 1825, the analysis of Otaheite and Ribbon cane, and admits that in those plants *one third of the sugar* exists in the liquid state, or as molasses.

A fortunate occasion permitted me to rectify, two years since, this old error of the existence of molasses already formed in the cane itself; an error which, without doubt, has caused and will still cause immense injury in the manufacture of sugar, by persuading manufacturers that the usual formation of molasses depends upon the nature of the cane itself; whereas, it depends at least in great part, solely upon the imperfect processes which they employ.

By subjecting to analysis the juice which was sent to me from Martinique, and of which the state of preservation was due to the method of Appert, very well performed by M. Péraud, I found that that liquid, the density of which was 1.088, yielded by simple evaporation a solid mass composed entirely of sugar; I estimated the weight of the residue at 21.3 per cent, and that of the sugar which it contained at 20.9 per cent.

Most chemists have regarded this result as sufficient to establish the non-existence of liquid sugar in the cane; the analysis of the same juice was repeated by M. Pélouze, who arrived at precisely similar results; it was likewise verified by Mr. Biot.

This celebrated academician, availing himself of his own beautiful discoveries relative to the actions which solutions of certain organic substances exert upon polarized light, found that the cane juice which I analyzed produced an effect, such "that it is exactly that which would be produced by an aqueous solution of crystallized cane sugar, containing the proportion of 20.2 per cent. by weight of that sugar."

"This physical proof, adds M. Biot, therefore, confirms the analysis of M. Péligot, and with greater probability, because it is calculated from determinations entirely independent of his; and the result which it has given is a necessary consequence of that which he obtained; besides I should not have invited the attention of the academy to it, if it had not offered an occasion to show what services this kind of physical observations so easily made, can render to the colonists and to sugar refiners."*

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* Comptes rendus des Séances de l'Académie des Science, t. 10, p 264.

Moreover, subsequently to these publications, M. Plagne, (*pharmacien en chef* of the navy at Brest,) entrusted in 1826 by the minister of the navy, with a mission to the West Indies, having for its principal object the improvement of the manufacture of sugar in the colonies, made known that, in the part of his report which relates to the analysis of cane juice, he demonstrated that it contains more than 20 per cent. of crystallizable sugar, and that the quantity of molasses or liquid sugar in it is almost inappreciable.

The account of the labors of M. Plagne was not published until May, 1840. It is to be regretted that this chemist did not make known much sooner the facts which he observed; those facts are, in my opinion, important; the researches which I have made, and which I assuredly would not have undertaken, if they had been known, accord entirely with the results obtained fifteen years ago by M. Plagne.

Lastly, M. Hervy, a promising young chemist, whose life was destroyed by a horrible accident in the midst of scientific labours, for which he was already distinguished, has left some observations on the analysis of the sugar cane, which are full of interest.— They were published in the first number of the *Journal de Pharmacie* of the year 1841.

The canes which served for the experiments of M. Hervy grew either in the hot-houses of the royal domain of Neuilly, or in the botanical garden of Bordeaux; they were cut into thin slices, and dried by gentle heat. By treating them with cold alcohol of 95 per cent., M. Hervy separated from them 3 per cent. of a deliquescent substance, neither saccharine nor saline in its nature, from which sulphuric ether separated a small quantity of wax; the residue, digested in boiling alcohol, yielded only crystallizable sugar.

"We may, therefore, assert," says M. Hervy, "1st, that there is *no uncrystallizable sugar* pre-existent in the sugar-cane; 2d, that the salts act upon the crystallizable sugar so as to produce the molasses; and that this action does not occur during vegetation, but by means of the manipulations."

Hence, that molasses does not exist in the cane seems to be an established fact, definitively settled in science and in the sugar industry; nevertheless, the old ideas upon this pre-existence, so convenient to be invoked in order to justify bad processes of manufacture, have acquired such dominion, that they still govern many of the colonists. M. Guignod, for example, contends* that dried canes contain, for 1,000 parts of sugar, 540 of molasses *in a dry state;* and, relying upon the tables of Dutrone Lacouture, to determine from the density of juice the quantity of sugar and of molasses it contains, he rejects as dangerous and altogether erroneous the experiments which I have published.

The preceding exposition renders it unnecessary for me to notice particularly the reasons which M. Guignod adduces to prove that

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* *Annales de la Société d'Agriculture, de la Martinique,* April, 1840, page 287.

those experiments, according to him inaccurate, can but do injury to the interests of the colonies, in which the mode of manufacture, in his opinion, leaves but little to be desired.*

I have determined by means of the unaltered juice, with one portion, the quantity of matter foreign to the sugar, and which is precipitated by the subacetate of lead; and with another portion, that of the fixed products contained in the liquid.

By treating a certain quantity of juice with the subacetate, drying the greenish white precipitate thus obtained, then weighing it and incinerating it, so as to destroy the organic or volatile matter contained in it, I found that the quantity of the latter was from 3 to 6 per 1000 of juice. The juice of the beet contains from 15 to 25 per 1000 of these same substances.

The fixed substances in cane juice, which consist of silica, common salt, the sulphates of lime and potash, etc., were obtained by incinerating the residue left by the evaporated liquid; their weight varied from 15 to 20 per 1000 of juice.

These several results accord with those which I have given in my memoir on the analysis of the cane juice of Martinique.

I have made a careful examination of the dried cane which was in a state of perfect preservation; the descriptive account of the substances, which terminates the first report, gives their origin, their mode of preparation, and the quantity of water lost by them when subjected to a gentle desiccation.

I have analysed them by digesting a definite weight of cane in water until the soluble substances were completely dissolved. The aqueous product was subsequently analyzed separately; the insoluble matter being well dried, furnished by its weight the proportion of woody fibre.

As it had been impossible for M. Dupuy to obtain on the spot a complete desiccation, which is with difficulty attained without such

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* Among the numerous complaints which M. Guignod makes against my work, is the following:

"It is stated that the juice received by M. Péligot indicated from 12° to 13° Baumé. It is very vague to say 12° or 13°; the juice marked 12°, or 12½°, or 13°, for a degree makes a considerable difference in the proportion of sugar," etc.

It is to be regretted that M. Guignod, before publishing his criticisms upon my work, did not read it attentively; for he would have found, on page 13, the words: "The density of this juice, taken precisely, is 1.088, the density of water being 1.00C. It indicates 11°.8 of Baumé's hydrometer." M. Guignod adds, "that juice of 12° is very rare, that 11° is not very common, and that it can only be considered to have 10° as a mean density."

This remark is certainly correct; but M. Guignod should have reflected, at the same time, that my juice was of the temperature of the air, which, when it is temperate, is lower in France by 10° or 15° than in Martinique; so that this difference of temperature causes the juice, for equal degrees of the hydrometer in the two countries, to contain different quantities of sugar. Thus, I found that the unaltered specimens of juice, which I received from M. Dupuy, presented an increment of more than one degree of Baumé's hydrometer above the degree indicated, with the temperature, in the memorandum which accompanied them. The bottles of juice sent from Martinique indicated generally, according to M. Dupuy, from 9° to 10° Baumé, the temperature being from 29° to 30° cent.; the same, at 20° centig., with the same instrument indicated 10° to 11°, Baumé. A juice from canes and second rattoons, for example, was found by M. Dupuy to be of the density 10° Baumé, at the temperature of 29° centig.; I found 11° at 20°, or 1.081 exactly for its density. For another which indicated 10°.5 Baumé, at the temperature of 27° centig., I obtained 11°.8 Baumé at 17° cent., and 1.089 for its exact density.

apparatus for drying as our laboratories are provided with, I found it necessary to commence with the determination of the amount of water which each specimen still lost by exposure to the temperature of 60° to 80° centigrade, in a stove, until its weight became stationary. To ascertain the total quantity of water contained in the canes, this new loss is added to that which had already taken place in Guadaloupe.

The following are the results of the analyses :

No. 17. *Plant Cane.* (First growth.) Cut up and dried for 24 hours by means of a temperature from 60° to 80° centigrade. (140° to 175° Fahrenheit.) One kilogramme left by desiccation in Guadaloupe, a residue of 279 gr., or 27 per cent. 100 parts of this dried cane lost anew 3.3 of water. It, therefore, contained 73.9 of water, and 26.1 of solid matter, composed of sugar, woody fibre, and salts. 3.132 gr. of this cane of 27 per cent. dry residue, left 1.03 of stove-dried woody fibre. Whence it follows that when fresh this cane was composed of:

| | |
|---|---|
| Water | 73.9 |
| Soluble matter | 17.2 |
| Woody fibre | 8.9 |
| | 100.0 |

No. 18. *First rattoons.* (Second growth.) Cut up and dried as above. One kilogramme left, at Guadeloupe, 290 gr., or 29 per cent. By renewed desiccation, this quantity became reduced to 28.3. 3.041 gr. of this cane of 29 per cent. left, by washing, 1.113 of woody fibre when dried. Which gives:

| | |
|---|---|
| Water | 71.7 |
| Soluble matter | 17.8 |
| Woody fibre | 10.5 |
| | 100.0 |

No. 19. *Second rattoons.* (Third growth.) Cut up and dried as above. The residue of the desiccation in Guadaloupe was 29 per cent.; it became equal to 26.4. By washing this cane I obtained:

| | |
|---|---|
| Water | 71.6 |
| Soluble matter | 16.4 |
| Woody fibre | 12.0 |
| | 100.0 |

No. 20. *Third rattoons.* (Fourth growth.) The desiccation in Guadaloupe left 29.3 per cent. This residue, dried again, was reduced to 27.9, and gave:

| | |
|---|---|
| Water | 73.0 |
| Soluble matter | 16.8 |
| Woody fibre | 10.2 |
| | 100.0 |

No. 21. *Knots of the cane.* Cut and dried by themselves. The residue, at Guadaloupe, was 29.4 per cent.; it also became 29.2. These yielded:

| | |
|---|---|
| Water, | 70.8 |
| Soluble matter, | 12.0 |
| Woody fibre, | 17.2 |
| | 100.0 |

No. 22. *Canes of* 8 *months.* The residue in Guadaloupe was 28.6 per cent.; it became 26.1, and gave:

| | |
|---|---|
| Water, | 73.9 |
| Soluble matter, | 18.2 |
| Woody fibre, | 7.9 |
| | 100.0 |

No. 23. *Canes of* 10 *months.* The residue, which was 29 at Guadaloupe, reduced to 27.7 per cent. These canes, when fresh, were composed of:

| | |
|---|---|
| Water, | 72.3 |
| Soluble matter, | 18.5 |
| Woody fibre, | 9.2 |
| | 100.0 |

No. 24. *Inferior part of the cane.* The residue was 28.8 per cent. at first, and reduced to 26.3. This part of the cane contained:

| | |
|---|---|
| Water, | 73.7 |
| Soluble matter, | 15.5 |
| Woody fibre, | 10.8 |
| | 100.0 |

No. 25. *Middle portion of the cane.* The residue was 28.6. It became 27.4. This part of the cane contained:

| | |
|---|---|
| Water, | 72.8 |
| Soluble matter, | 16.5 |
| Woody fibre, | 10.9 |
| | 100.0 |

No. 26. *Superior part of the cane.* The residue was 28.2 per cent. It reduced to 27.2. This part contained:

| | |
|---|---|
| Water, | 72.8 |
| Soluble matter, | 15.5 |
| Woody fibre, | 11.7 |
| | 100.0 |

By treating these specimens of cane with alcohol and with water, I ascertained that almost all the soluble matter which they contained was crystallizable sugar.

I also established the existence of the *deliquescent matter* of M. Hervy. This matter dissolves in very strong alcohol without heat; but it was impossible for me to determine the exact quantity, because a small quantity of sugar always dissolves at the same time, however concentrated the alcohol may be. M. Hervy says that he extracted from dried cane 3 per cent. of deliquescent matter. This quantity is certainly excessive: in the first place, M. Hervy believing that the cane was dried in 15 minutes by a temperature of 60 degrees centigrade, does not seem to have been sufficiently aware of the difficulty of absolute desiccation; then, having treated the cane with alcohol of 95 per cent., it is impossible that a small quantity of sugar should not have been dissolved, although his deliquescent matter was without a saccharine taste.

It appears, by comparing the analyses which I have just enumerated, that they differ very little from each other. The plant canes and rattoons offer nearly the same composition.

The canes of 10 months contain nearly one per cent. more of woody fibre than those of 8 months: they seem also to contain a little more sugar.

The knots contain much more woody matter than the other parts of the cane. This result was certainly to have been expected; but what was not anticipated, the proportion of water contained in those knots is the same as that in the other portions, so that the difference falls wholly upon the sugar. The juice obtained by crushing these knots should be considerably poorer in saccharine matter than the ordinary juice.

The comparative analysis of the cane cut into three portions should be of interest. The results which I have obtained prove that the differences in the proportion of sugar are so small that they may depend on errors inherent in the indirect method which I employed. Those differences can only be determined with certainty by analyses made on the spot by an experienced chemist.

These results collectively lead to the conclusion, that the mean composition of the cane is at present known; they fully establish the fact that the gummy, mucilaginous and other substances, which were supposed to be contained in that plant, do not exist, any more than uncrystallizable sugar.

I will now allude to several questions important in many respcts, which are connected with the results which I have established.

Molasses does not pre-exist in the cane—that is now certain; what is the source, then, of that which is always obtained in the extraction of its sugar? and what are the means to be employed, if not to avoid its production entirely, at least to diminish the proportion?

I do not believe that any chemist or manufacturer can at present answer these questions in a manner entirely satisfactory; nevertheless, it must be admitted that, within a few years, they have been greatly elucidated by direct experiments, and by reasoning and analogy.

I think it the more useful to discuss them somewhat fully here, because they concern not only the manufacturer but even the colonial culture; and because the considerations which I may submit upon this subject, though they will not be new to every one, yet seem not to have attracted hitherto the attention of the persons who are the most interested in their proper appreciation.

If the chemical composition of the cane is not constant; if it varies with the age of the plant, with the nature of the soil, and particularly with the influences of climate which have attended its germination and development, the proportions of sugar and of molasses obtained in the manufacturing operations varies in turn between much more extended limits.

Thus it results from information gathered by M. Dupuy, in Gaudaloupe, and set forth in the first part of his report, that in making 100 parts of sugar of ordinary qualities in that colony, from 30 to 60 parts of molasses are obtained. M. Guignod says that 100 parts of juice of the colonial density 11° Baumé can yield by careful working 17.5 of first and second sugars, which supposes a production of a residue of 25 per cent. nearly of molasses; lastly, I am informed by M. Vincent, a very skilful sugar manufacturer from Bourbon, that by using bone black and a vacuum pan for concentrating the syrups, the molasses is reduced almost to nothing.

These differences obtained with canes which are nearly of the same saccharine richness, show that the processes of extraction exert a very variable influence upon the production of the molasses; they also prove in their turn that it is not already formed in the cane, but that it results from the destruction of a quantity of sugar which is evidently equal to the weight of molasses produced.

Among the causes of this incontestable destruction, some may be avoided at least in part; others must continue to exert their evil influence, because they depend less upon the processes of working than upon the nature of the cane and of the sugar derived from it.

I will point out and discuss successively these various causes:

### I.—*The viscous fermentation.*

When cane juice is left to itself, the sugar which it contains is transformed spontaneously into a substance which is not sweet, and which renders it thick, viscid and ropy as if it contained gum. The higher the temperature of the atmosphere, the more readily is this substance developed; the longer the juice remains in the reservoirs into which it flows from the mill, the greater the quantity produced.

Its formation is so frequent in the colonies that this substance has long been admitted to pre-exist in the juice in its sound state. It is the gum which authors describe as existing in variable proportions.

The properties of this substance are very little known. I have intended to make it shortly the subject of a particular investigation. It is known only that it is insoluble in alcohol, which precipitates it from its aqueous solution in the form of a pearl white flexible

net, which, by desiccation, assumes the appearance of dry kneaded crumb of bread. Its properties and elementary composition establish for it a parentage like that of starch.

I have ascertained, by aid of the microscope, that its formation takes place under the influence of, or rather in the presence of a substance which exists in very small globules in saccharine juices which are not acid, and renders them unsettled; also, when the juice has been defecated with bone black it becomes incapable of undergoing this peculiar fermentation as rapidly.

This substance is injurious for several reasons. It is formed at the expense of a certain quantity of sugar; it renders the evaporation of the syrup difficult. When the concentration is finished, it hinders the crystallization of part of the sugar which has not been destroyed. Lastly: at the same time that it is formed it determines or precedes the production of an acid, which, in turn, contributes probably to the destruction of another portion of sugar.

We can prevent its formation by heating the juice, or by defecating it immediately after its extraction, the action of the substance, which plays the part of a ferment, being destroyed at the temperature of boiling water. It is possible that the same end might be accomplished by passing the juice through bone black as it flows from the mill. When once rendered limpid, by this or any other method, it will keep much longer without alteration.

One of the advantages of the process of maceration, which I have discussed, would be the more ready avoidance of this viscous fermentation.

II.—*The employment of too high a temperature in the concentration of the juice.*

This cause of alteration is so well known that it is unnecessary to dwell upon it.

It is known that, in pans exposed to the direct action of the fire, it often happens that the juice is heated to a temperature so high that a quantity of the sugar is converted into a brown uncrystallizable substance, called *caramel*, which is deliquescent. The existence of caramel in the strike prevents the crystallization of part of the sugar, and thus produces an additional quantity of syrup or molasses.

Nobody doubts, at this day, that those pans in which the strike cannot be caramelized furnish a more abundant, drier, and less colored sugar. Apart from the inconvenience which their high cost and expensive repairs occasion, vacuum pans seem to unite the conditions best adapted to the concentration of syrups, since evaporation is performed in them rapidly, and at a temperature inferior to 100° centigrade, (212° Fahrenheit.)

III.—*Excessive acidity or alkalinity of the juice.*

Cane juice becomes, under circumstances not very well known, strongly acid, while it is nearly neutral in the fresh and healthy

cane; this acidity is due to acetic and lactic acids, which form during this alteration.

In my opinion, the action of those acids has been badly understood. It is believed that they cause the transformation of cane sugar into fruit sugar—into *glucose;* a variety of sugar which is known to be uncrystallizable when it contains a small quantity of foreign matter. Doubtless, if the acetic and lactic acids were more energetic it would be thus; but direct experiment proves that when they are brought into contact with a pure solution of sugar, even for a considerable length of time, they do not cause it to undergo any change. The direct action of those acids is not, therefore, to be feared; what should be dreaded is their formation itself, because it indicates always a previous change in the juice.

It is known, indeed, that as soon as a syrup commences to undergo alcoholic fermentation, its sugar, before being changed into carbonic acid and alcohol, first suffers profound modification: it becomes fruit sugar, and ceases to be crystallizable; the alcohol afterwards forms; this substance is transformed in turn, under the oxidizing influence of the air, into acetic acid; so that that acid succeeds, indicates, but does not determine the formation of the molasses, which is due chiefly to the existence of fruit sugar.

Moreover, it does not appear that alcoholic fermentation occurs ordinarily in cane juice, which is, on the contrary, very subject to viscous fermentation, as we have already stated. The latter is attended or followed by a certain quantity of lactic acid, which is produced, as well as the viscid matter, at the expense of the sugar. Recent researches authorize the following views upon this subject:

The analysis of nitrogenous substances has shown that those which abound in animals, such as albumen, fibrin, caseum, are identical with those found in much less quantity in vegetables; thus the nitrogenous substance, called vegetable albumen, which exists in the cane, and especially in the beet, seems to have all the characters of the caseous substance of the milk of animals.

Again: The experiments of M. Thénard, together with those of MM. Boutron and Frémy, have shown that when an animal substance in spontaneous decomposition is brought into contact with neutral vegetable substances, such as sugar, gum, starch, etc., it transforms them into lactic acid; it is thus that the caseum acts upon the sugar of milk; and thus that cane sugar, in contact with animal membrane, is converted into lactic acid.

Now, since the identity of the nitrogenous substances of the vegetable and animal kingdoms seems to be demonstrated, and since cane juice contains caseum, it is probable that it is the spontaneous decomposition or putrefaction of that substance which produces the lactic fermentation, and likewise the viscous fermentation.

But whatever may be the case in relation to this subject, it is certain that the dosing of cane juice with lime preserves it, at least for some time, from those alterations.

The action of lime upon saccharine juices offers different phases, to which it may be useful to call attention; for there are also several dangers in connexion therewith which should be avoided.

In the first place, a difference should be established between the effects of defecation of cane juice and those of the same operation upon beet juice. For the latter, defecation is indispensable—the lime separates from it a large proportion of foreign substances, which, as long as they are united with it, prevents the crystallization of its sugar entirely. For cane juice, defecation is useful—it is even necessary, but not in the same degree, nor to the same extent; for the foreign matter which exists in this liquid is in such small proportion that all its sugar may be obtained in a crystalline state, without the intervention of lime. I have demonstrated these facts in former works.

I am convinced that, if cane juice could be worked without having already undergone, and without its being possible for it to undergo any alteration, its defecation would be unnecessary; for the principal object thereof is to assure its good keeping, or most frequently to arrest and limit the spontaneous modifications which it experiences.

It is, moreover, chiefly in clarifying the cane juice, in order to free it of substances which render it turbid, and act subsequently as agents of fermentation, that defecation is useful; it is equivalent to a rapid filtration; it does not separate completely the nitrogenous substance which produces viscous fermentation, for the defecated juice becomes thick when it has been kept some days; but it retards its action, especially because it renders it necessary to heat the liquid, and frequently even to boiling.

When cane juice contains considerable quantities of free acid, lime, in saturating them, introduces uncrystallizable salts, which keep a portion of sugar in the liquid state; this, without doubt, is the cause to which the large proportion of molasses is to be ascribed.

If the juice has commenced to suffer alcoholic fermentation, the defecation acts in a different manner; it causes, at the same time, new advantages and new disadvantages; it saturates the carbonic acid; it combines with the glucose (fruit sugar) which accompanies or precedes the formation of that acid; then this combination suffers almost immediate destruction, the glucose becoming an acid (*glucic acid*) under the influence of the lime. The action does not stop with the formation of *glucate of lime;* for that salt is transformed into another, which is of a dark brown color—the *molassate of lime*—and which constitutes, together with caramel, the coloring principle of brown sugars and of molasses.

Hence it would seem that the use of lime in large quantity is not as advantageous as it is thought, when altered saccharine juices are worked; but the daily practice seems to demonstrate the contrary. It is well known that, in the beet sugar manufacture, more lime is used at the close of the season than at its commencement; it is also known that the products then obtained are always less abundant and much more colored.

We may form some idea of the advantage which is obtained by increasing the proportion of lime, when the juice has suffered alteration, by considering the fact that glucate and molassate of lime

are more fluid in concentrated syrup than glucose itself, so that the destruction of the latter becomes preferable to its preservation, because it offers opposition by its viscid consistence to the crystallization of a larger proportion of sugar.

I have established by direct experiments that molasses always contains much of the two calcareous salts, the formation of which I have just explained.

Defecated juices should be as neutral as possible. As this neutrality cannot be obtained in practice, they are very slightly alkaline when properly performed. This excess of lime produces glucate of lime, if the juice is altered, and saccharate of lime, if it be sound. The latter salt is uncrystallizable—it coagulates by heat; when it exists in sufficiently large proportion in concentrated juice, it renders evaporation sluggish and difficult. It also contributes to prevent the crystallization of a portion of sugar.

Lime employed in excess should be particularly injurious in the colonial sugar houses, where animal black is not employed; for it should be understood that it is by absorbing any excess of lime, much more than by decolorization, that bone black has become so powerful an auxiliary in the manufacture of beet and cane sugar.

There is another inconvenience arising from the use of lime, at least in some localities: it is the production of a calcareous crust on the inside of the evaporating pans.

Mr. Avequin, in a recent article, has called attention to the formation of the *cal* (the name by which that crust is designated) in the manufacture of sugar in Louisiana, where he resides.

According to Mr. Avequin, several days working are sufficient to cause the formation of a crust in the sugar pans, which adheres to them the more strongly the longer they are used without cleaning. This *cal* hinders or retards the ebullition of the juice, for it conducts heat very badly. Its cracking during the work manifests itself by a peculiar hissing sound, which is produced in the pan. At the same time the saccharine liquid infuses itself between the crust and the pan, which, being coated with a non-conducting substance, becomes much hotter than the liquid, and puffs of white vapor appear in consequence of the decomposition of a portion of sugar.

To remove the *cal* from a pan, the sugar makers are obliged to heat it to redness, to *burn* it, as they say. The crust is carbonized, and detaches itself in large flakes, which are sometimes, says Mr. Avequin, 6 or 8 centimetres (2 or 3 inches) thick. The *cal* is so hard that the hammer and chisel produce but little effect upon it.

Mr. Avequin attributes the troublesome formation of this substance to the biphosphate of lime, which, according to him, exists in very large quantity in the cane; but, besides that this assertion is in contradiction with all the analyses which prove that the phosphate of lime does not exist in greater proportion in this plant than in the saps of other vegetables, the examination which he has made of that substance (an examination which, indeed, leaves much to be desired) leads to a conclusion quite different from his own. For Mr. Avequin found that 1,000 grammes of *cal* yield, by suit-

able incineration, during which much inflammable gas escapes, 492 grammes of a calcareous residue; and, because 100 grammes thereof leave, by successive treatment with nitric acid and ammonia, 92 grammes of a substance which seems to have the character of phosphate of lime, he admits that the formation of the *cal* is due essentially to the deposition of phosphate of lime during the concentration of defecated juice.

From this analysis itself it is evident that the *cal* is really formed of an organic substance, which exists in it in the proportion of 51 per cent. This substance is combined with the lime, and is mixed with the phosphate of lime.

What is that substance? What is the origin of that large proportion of phosphate of lime? It is for the purpose of contributing to the solution of these questions that I have related the experiments of Mr. Avequin. Does not, for example, the phosphate of lime proceed from the use in defecation of lime prepared by calcining oyster shells, which, as is known, contain a large proportion of phosphate of lime? Lime of such a nature has been, I am assured, employed in some places. We can readily understand how such lime, if put into acid juice in insufficient quantity to saturate it, would introduce the phosphate of lime. Again, does not this *cal* contain carbonate of lime, which, held in solution by the free carbonic acid of fermented and badly defecated juice, would be deposited when that acid is driven off by the ebullition of the liquid, as occurs with those kinds of water which are called encrusting (*incrustantes?*)

These questions being settled, it will doubtless be easy to prevent the formation of an accidental substance so injurious to the manufacture of sugar.

### IV.—*The existence of mineral salts in the cane.*

The salts which exist in solution in cane juice contribute also to the formation of molasses. Their influence is, perhaps, less than that of the causes which we have enumerated, but it is assuredly more difficult to avoid.

Among those salts is common salt, which forms, by combining with sugar, a deliquescent compound, in which one part of salt, united with six parts of sugar nearly, renders uncrystallizable still another portion of sugar. We may estimate, I think, at from 10 to 15 per cent. the quantity of sugar which 1 or 2 per cent. of soluble salts would hinder from crystallizing.

Is the quantity of these salts proportional to that of the sugar? This question is of high importance, and the elements which we now possess are insufficient for its solution. The comparative analysis of juices, rich and poor, in sugar, and the determination of their salts, would doubtless lead to its solution.

If, as is infinitely probable, the secretion of those saline compounds, which are the same in the cane as in most vegetable juices, is independent of the formation of the sugar, it would be very useful to subject the manures used in the cultivation of that plant to a careful investigation. It is essential, indeed, to distinguish

among plants those which should serve directly for food to man or animals, from those which are only cultivated because they elaborate products which are to be subsequently extracted by particular processes. If the action which manures exert upon the development of the first is but partially known, the influence of the same manures, if not upon the quantity, at least upon the quality of the second, has not yet been sufficiently studied. Yet, it is known that the most energetic manures are those which are least adapted to beets designed for sugar making; and that those plants appropriate and assimilate, with astonishing avidity, all the salts which are contained in the surrounding soil. I have analyzed, for instance, beets which grew in grounds too much enriched with dung, and found them to contain 2 per cent. of nitre. By digesting them in warm dilute alcohol, after drying them, that salt separated in crystals, before the sugar.

It is probably to this same cause, viz., the presence of soluble salts in too large quantity in the soil, that we should attribute the difficulty of working canes which grow in new lands, recently cleared and rendered too fertile by the salts furnished by the incineration of the trees which covered them. Those canes present a great development, a luxuriant vegetation, but yield syrups almost uncrystallizable.

The influence of unripe canes upon the quality of cane juice—an influence which the colonists agree in considering most pernicious—should probably be attributed to the same cause. I do not think that we should admit the existence, at any period of the growth of the cane, of an organic substance which precedes the formation of the sugar, and which diminishes or even hinders, by its presence, the crystallization of the latter. The existence of such a substance is generally believed in the colonies, where they call it gum, mucilage, &c.; but it is almost certain that the formation of sugar is similar in the cane and in other saccharine plants, which are not acid. Some years since I ascertained that, at all periods of the growth of the beet, sugar exists in nearly the same proportions, relatively to the water and other soluble substances in it; so that in very small beets, of the thickness of a goose quill, I found a juice as rich in sugar as that of much larger and older beets. It is not until the beet has attained its full growth, and its increase has ceased for some time, that the proportion of sugar becomes greatly augmented.

It is probable that the same thing happens for the cane; unripe canes contain always crystallizable sugar only; mucilage does not exist in it at any period; and if they are more difficult to work, if they yield less sugar, it is to the predominance of the salts which are secreted before the sugar that the difficulties and losses are to be attributed; it is they which render a greater proportion of sugar uncrystallizable.

The same explanation may be given for the variations observed, in regard to the taste, in different parts of the same cane; the top offers a taste less sweet, because it contains more saline matter

than the inferior portion, which is more advanced towards maturity.

If these conjectures are well founded, a careful selection of the manures to be used should always be made; those which are rich in vegetable matter, of easy decomposition, and poor in mineral salts, are probably the best. In Guadaloupe, they make much use of a manure known by the name of sea-filth, (*boue de mer*,) which collects, in quantities more or less considerable, in various places upon the shore, and which is composed of an argillaceous earth mixed with shells and vegetable matter of the family of the algæ, etc. This manure, according to the analysis made of it by M. Dupuy, who extols its efficacy, contains, when dried, 2.5 per cent. of soluble saline-matter, in which common salt predominates.*

It is not to be doubted that this manure is well adapted to promote the development of the canes, for long experience has demonstrated it; but do not the salts which it contains contribute to diminish the yield of the juice in sugar, so that with a manure less saline, less cane would perhaps be obtained, but more sugar? This question is one which it would be useful to settle, and which careful observations by the colonists would determine. Manure, at the same time, two equal fields of cane—one with this *boue de mer*, in the ordinary manner, and the other with the same manure washed with rain water; ascertain the weight of canes and of sugar yielded by each of these fields, taking care to proceed always in the same manner; assuredly, this is an experiment which can be tried without much expense or difficulty.

Probably the advantages produced by the action of manures in the development of canes are somewhat counterbalanced by the inconvenience they cause by the salts which they introduce into the plant. Certain manures of very doubtful value, in view of their composition, are imported from Europe at great expense. May not the advantage which attends their employment in the colonies be due chiefly to their inferior efficacy?

I have now enumerated the principal causes which tend to produce molasses in the extraction of sugar. If the last, which depends on the nature of the cane itself, cannot be avoided, at least in the present state of our knowledge concerning the formation of vegetable juices and the rational culture of plants, the others may disappear in great part under intelligent management. In discussing those causes I have not had the pretension to say anything which is not almost admitted by the chemists, at least by those of them who have occupied themselves with these questions. But it is not for them that this work has been done; if it should receive any publicity, the colonists, whom it chiefly concerns, will perhaps accord to me credit for having rendered some vague points of their operations more precise, and for starting some questions, of which the solution, which they can determine, interests them in a high degree.

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* I have found, by an analysis of this manure, that it contains 4 per cent. of soluble matter, 1.5 of which is common salt. It also contains 27 per cent. of organic substances.
E. P.

This discussion of facts, either probable or certain, which give rise to the production of molasses, would be incomplete if I were not to add to it some reflections upon the effects which that substance exerts upon the crystallization of the sugar.

Although it be very evident that the proportion of molasses produced in the manufacture of cane sugar is now much too great, I am far from pretending that the production of that residual matter should be entirely avoided. I even believe that when all the causes of alteration which have been enumerated above should be overcome, the sugar would not be produced *in a commercial condition* unless a certain quantity of mother liquor, of uncrystallizable molasses sugar, were (*then designedly*) formed.

This assertion demands some development. Sugar, like all substances susceptible of crystallization, can present various aspects, according to the circumstances under which it solidifies. If its passage from the liquid to the solid state be sudden it has a vitreous appearance, like that of barley sugar; if, on the contrary, that passage be very slow, it forms prismatic crystals, which are transparent, and as large as those of rock candy; between these extremes there are intermediate conditions.

The crystalline appearance of commercial sugar can be obtained only by the development of crystals rapidly and freely in a dense and liquid medium; if this medium itself should crystallize, the mass would be confused, the crystalline grains would not be separate, and the sugar thus produced would be rejected in commerce, accustomed as men are to estimate the nature and value of articles only by means of their form.

It is, therefore, in this liquid mass that commercial sugar is and should be formed; but it may exist without being deprived of the faculty of crystallizing afterwards in its turn. Let pure sugar be dissolved in water, and the solution be concentrated to the extent suitable to avoid its alteration, one-half of the sugar only will crystallize; but the mother liquor, the syrup, which becomes a saturated solution at the ordinary temperature, may, by a new evaporation, rapid or slow, furnish new crystals; so that by successive drainings and evaporations all the sugar employed may be recovered in the solid state.

If this same sugar, when in the state of syrup, be treated with a mixture of alcohol and ether, which causes its rapid precipitation, the thick liquid thus obtained will settle in a short time; and the sugar separated in this manner, though pure, will be destitute of transparence and of the particular aspect which characterizes commercial sugar.

To recur to the question which M. Guignod addressed to me in one of his articles relating to my first work. "But has M. Péligot really obtained 20 per cent of commercial sugar?" I will reply! no, I did not obtain 20 per cent. of commercial sugar; this follows from the very description I have given of that sugar. But it would have been commercial if, instead of operating in a small way, upon a few hundred grammes of cane juice, by means of alcohol and rapid evaporation, I could have worked upon a larger

scale; for this sugar, I repeat, was free from uncrystallizable sugar and from molasses.

However, what was not possible for me to do was executed by M. Plagne; by operating upon 4 kilogrammes of cane juice, he obtained by concentration and successive crystallizations, 832 grammes of crystallized sugar, of a yellowish white color, drier than the ordinary *cassonades* of Martinique; this 20.8 of sugar bore the characteristics of commercial sugar.

Finally, M. Guignod expresses himself as follows: "M. Péligot should have obtained what I have often had in my small operations, my form being a funnel, a sort of concretion; I say *a sort of*, because the true concretion seems to indicate the absence of molasses by a very high concentration which caramelizes and attenuates the crystallization, which would have been obtained by a moderate concentration. There is also attenuation of crystallization, with this difference, that there is no caramelization, and that the shade of color remains beautiful. The shade of mine was beautiful also; neither had I any molasses, or rather there was no appearance of any; but did I estimate its quantity? Did I suppose that I had crystallized all the matter remaining after the evaporation of the water, and the removal of the extraneous matters by our method of purification? Did I suppose I had obtained commercial sugar? Certainly not; I obtained the ordinary results to be anticipated in crystallization in small vases—what takes place in the vats in the manufacture on a large scale, when too small a layer of concentrated syrup, a quarter of an inch for instance, in place of an inch and a half is used; I obtained an excessively attenuated crystallization, occurring in such a state of division that the molasses itself, divided in an immense number of interstices, could neither separate nor flow off. In fact, it was supposed that the infinitely small rudiments of crystals, being seized by a too sudden cooling of the mass, in the midst of very thick molasses, could not approach so as to form larger crystals by superposition. Sugar of this kind becomes as hard as marble. Is this taken for commercial sugar? Is this the 20 per cent. of sugar?"

We see in this passage, some parts of which in truth are quite unintelligible to me, that M. Guignod obtained 20 per cent. of inferior sugar; now I think that I established or rather asserted the fact, that its commercial appearance depends solely upon the medium in which the sugar crystallizes, so that in causing the sugar to crystallize in molasses, for instance, which yields no crystals, we would obtain in a merchantable condition the 20 per cent. of sugar which the juice really contains. I may add, that frequently the molasses necessary for the crystallization of sugar can likewise be crystallized; such are the drippings (*sirop d'égout*) which is the result of a well conducted operation. It is difficult to comprehend why the colonists do not profit by the sugar which they could easily produce by a new concentration of the syrup, provided the operation was immediate; for in preserving it for a long time, as is most frequently the case, it becomes decidedly uncrystallizable,

and it is thought that then it is more advantageous to convert it into rum or use it as food for cattle.

It is certainly to this carelessness that we must attribute the large proportion of molasses which they get, since their juice yields no more than 12 per cent. of commercial sugar. It seems that in adding to new concentrations recent drippings, so as not to preserve any molasses, the yield in sugar would be much increased, and consequently the revenue also, since the crystallized sugar has always a value at least five times greater than that of molasses. This practice succeeds even for beet juice, where the uncrystallizable substances exist in a much greater proportion. However, it is not possible in all cases, unless the molasses be the result of operations in which the accidental causes of the destruction of sugar previously discussed have been carefully avoided.

After this long but necessary discussion, I return to the labors of M. Dupuy.

In the course of the second part of his memoir, he reports some experiments, made on a small scale, for the extraction of sugar from dried canes. These experiments were satisfactory, when he operated upon canes recently dried; the yield in sugar amounts to 60 per cent.; but dried canes, exposed for three months to the ordinary influence of the atmosphere, gave only 34 per cent. of an oily, discolored sugar, having none of the qualities of commercial sugar. In analyzing the third part of the memoir of M. Dupuy, I will recur to the important question of using dried cane.

M. Dupuy then discusses the processes employed in practical operations upon dried cane; he sets forth the advantages and inconveniences of this method of manufacturing sugar.

Finally, he describes the actual condition of the manufacture in the colonies; he exhibits its imperfections, and indicates the different means which seem to him to be the most expedient for immediately diminishing, with little expense, the enormous loss of sugar incurred by a method so much at variance with the constant progress of all other branches of industry.

The latter portion of M. Dupuy's work is well treated; the advice he gives to the colonists is wise and reasonable; followed by several manufacturers, whose names he gives, it has borne good fruit.

It would be impossible, however, to analyze this discussion, interesting as it is, without entering into details, which the limits of this memoir, already too long, will not permit. To give publicity to the researches of M. Dupuy would doubtless be profitable to the progress of the colonial industry.

I pass then to the third part of the report of M. Dupuy, which was addressed to me five months ago, through the medium of the minister of agriculture and commerce.

*Third part of the memoir of M. Dupuy, dated 10th September, 1841.*

M. Dupuy repeats what he previously demonstrated, that the mills cause an average loss of twelve to fifteen per cent. of cane

juice; he mentions that this fact is now more generally admitted by sugar planters, in consequence of the proofs he made in 1840 upon the rolling of canes, the exactness of which proofs he has again verified upon the last crop. A few colonists, he adds, have recently adopted good and solid iron mills with horizontal rollers, the action of which being more regular and more powerful, gives seventy to seventy-two per cent., in place of fifty-five to sixty per cent. obtained by the old mills.

He reverts to the process of desiccation and the exportation of dried cane to France. This process was recently commenced by a company in the metropolis, in an establishment built expressly for the purpose, upon a lot of M. de Jabrun, upon the bay of Mahault.

He first gives the experiments which he made upon dried cane, in order to discover their richness in sugar at different periods of the year.

The canes were cut, obliquely to their length, in short sections of two or three millimetres, then dried by fire, for twelve or fifteen hours, at 60 or 80° centigrade; some were dried by two or three exposures to the sun, at the temperature of 45° centigrade.

These canes were macerated in cold water for several hours. M. Dupuy determined that one hundred parts of canes, reduced to thirty parts by drying, when macerated three hours in five hundred parts of water, at the mean temperature of 26° centigrade, give a liquid indicating from 102.5 to 103.5 degrees of Collardeau's densimeter; by making several successive macerations, and evaporating the combined liquors, he obtained a quantity of commercial sugar equal to from twenty-four to thirty per cent. of the weight of the canes.

This sugar was obtained without the usual defecation by lime; and the liquors were neutral to test paper.

M. Dupuy remarks that by this method, according to his experiments, nine kilogrammes of sugar can be produced from one hundred kilogrammes of fresh canes, instead of seven kilogrammes, which the best arranged establishments now obtain. It is evident that this increase in product is still not so considerable as it should be, since the canes have lost seventy per cent. of their weight of water, containing about two parts of sugar for one of woody matter. The use of methodical steepings, until complete extraction, would doubtless have furnished M. Dupuy a more considerable yield, by a process quite as practicable.

M. Dupuy then describes the building constructed in Guadaloupe for the purpose of cutting and drying the fresh canes, and for pressing them when dried; it is in this building, which is of vast dimensions and furnished with well contrived arrangements, that the company for desiccation proposed to prepare and send to France, in July, 1841, fifty thousand kilogrammes of dried cane, for a large experiment in a sugar refinery in the environs of Paris. Unfortunately, the bad construction of the part of the apparatus intended for drying the cane prevented it from performing its duty in good time, so that it was necessary to defer this proof until another season, after having proved by the desiccation of some thousands

weight of canes that, with the exception of the bad mechanism of the part of the apparatus referred to, the rest of it gave good results.

The important question of using dried canes is then still pending; for the postponement of this operation cannot be justly considered an unsuccessful result. While earnestly desiring that this operation may succeed—that it may give to commerce an increase of freight—to the colonists a greater yield, and, consequently, a greater income, and to the metropolis a more saleable sugar—I cannot forbear from making some observations upon the chances of success which it seems to me to have, or, rather, which it is now supposed to have.

I may remark that, in indicating the different means which it seems expedient to use for obtaining a more considerable yield in juice and sugar, I have scarcely mentioned this process of desiccation, which is, nevertheless, the one most praised of late, and which was the first to cause experiments to be made on a large scale.

The motives for this reserve have already been given in the memoir which I published in 1840 upon the sugar cane of Martinique. In speaking of the evident alteration which the dried canes received from that colony had undergone, I thus expressed myself:

"These different circumstances render illusory, in my opinion, the desiccation of the cane as a basis for a new method of extracting sugar. I will not discuss here all the reasons which render the process of desiccation advantageous in certain cases for the beet, but on the contrary useless, and perhaps injurious for the sugar cane; but it has been proposed latterly to bring dried canes from the colonies, in order to extract the sugar in France, I have indicated summarily the principal causes which prevent, in my opinion, the economical treatment of this future colonial export."

In spite of this opinion, put forth in that first work and since repeated, it has been attempted to connect my name with that of M. Pelletan, in the invention of the process of desiccation of canes. That M. Pelletan may have adopted my analysis in establishing his process is very possible; but that I have participated in the propagation of this process is untrue, since, on the contrary, I spoke beforehand in a manner perhaps too positive of the inconveniences which I thought it presented.

These inconveniences are of many kinds; some are discussed in the *Annales de la Société d'Agriculture de la Martinique*, by M. Guignod, with whom, for this time only, I nearly agree. M. Guignod established by figures that this operation is not economical. This conclusion is probable; yet the reasons which M. Guignod presents are such as to render it a debateable question.

This gentleman supposes that dried canes contain—

| | |
|---|---|
| Begassa | 50 |
| Sugar | 33 |
| Molasses | 17 |
| | 100 |

He admits that this molasses is in a dry condition, and he boldly calculates the quantity from the old tables, essentially false and erroneous, of Dutrône Lacouture.

It is known that many enlightened colonists, among whom in the first rank is M. de Jabrun, concur in the opinion I have just given upon the impossibility of founding, upon desiccation, a process of working advantageous for their country. Without discussing here the arguments presented in favor of this method, I will only say that there has not been sufficient importance attached to the point which I think governs the whole question: the preservation of the sugar in an unaltered state in dried canes.

This preservation appears to me to be very doubtful in a practical point of view.

Doubtless dried cane, kept in a dry place, may furnish almost the entire extraction of the sugar in a crystalline state; and doubtless the 17 per cent. of pre-existing molasses is at this day, for everybody but M. Guignod, an absurdity which it is useless to notice further; but can the complete desiccation, easy to execute in a small way, be realized when the operation is conducted upon a very large scale? Admitting that it can be obtained, is it possible that the bundles of dried cane, packed even by the hydraulic press, can be entirely preserved, during a long voyage, from atmospheric humidity, and from accidental contact with rain or salt water? Now, it is notorious that humidity, whatever may be its origin, from which it will be so difficult to preserve entirely a substance so porous, so bulky, and of so little value as dried sugar cane, is a permanent cause of destruction, the progress of which is rapid and disastrous. Under the influence of water, organic substances mould and become acid; under the influence of acid, sugar disappears.

Experience unfortunately has already demonstrated how much this cause of destruction is to be feared; for the samples of dried cane, which I received at different times from the colonies, (excepting those placed in well secured bottles,) all exhibited a very decided acidity, and, consequently, an almost total absence of crystallizable sugar.

It is to this preservation of the dried cane, during the voyage, that I would have directed attention had my opinion been heard before this new process of extracting sugar had been undertaken. This problem governs all others by its importance. I think it cannot be solved.

Moreover, it is much to be regretted that, among the various ways which may be taken to extract a greater quantity of sugar from the cane than that now obtained, the most uncertain and the longest has been selected. I am convinced that, apart from the principal difficulty which I have just mentioned, the separation of the sugar from the begassa, at the place where the cane grows, will always be preferable, in point of economy, to the long transportation of these two products unseparated.

In my opinion, also, if the drying of the cane offers any advantages, it is only on condition that the extraction of its sugar takes

place upon the spot. The experiments of M. Dupuy are important, as proving that, by means of macerations, evidently insufficient, one-third more sugar can be extracted from dried canes, without even employing lime, than from fresh canes treated in the ordinary manner. Whatever else may be said of it, the necessity of going to a distance to make these macerations does not exist. To seek good processes of extraction in France, and then to report them to the colonies, would always be more reasonable than to send the products themselves to be submitted to those processes. It has been supposed that the begassa would have here a value which would in part cover its expense. It would be employed, it is said, in the manufacture of paper. The experiments, made with such a design, prove that it is fit for that use.

It must be observed, however, that the begassa must be replaced by a fuel certainly of greater value than that which it represents in the colonies: it would not serve for the manufacture of paper, unless its value in France were almost nothing. The successful experiments which have been made with it prove nothing in favor of its use. With what substances (alas!) is not paper now made? A fact which does not prevent rags from being rare and costly, because good paper can be made of them only. Begassa is much inferior to cotton in this industry, though a little better than straw and other naturally fibrous substances: it can be considered only as a valueless residue.

Here ends, Mr. Secretary, the task which you did me the honor to entrust to my charge. I have sought, by the attentive discussion of the documents which we at this time possess, both upon the manufacture of sugar and the composition of the cane, to establish distinctly the present and future position of this great colonial industry. The facts which I have set forth, and the opinions which I have given, will doubtless find contradictors; each one, according to his interest, will give them a different interpretation, as has happened to my preceding memoirs upon the beet and the cane; some will see in this work the finger of an advocate for the colonies; others, on the contrary, will find arguments in favor of beet sugar. As for myself, I will give no opinion upon the influence which these results may have upon the question of domestic and colonial sugars, a point so much contested. Without prejudice of locality or position, I have had in accomplishing my task but a single end, that of seeking the truth.

Permit me, sir, in the name of progress, which each of us seeks to favor, to call your attention to a point in legislation which opposes, in my opinion, all the actual ameliorations which your enlightened solicitude endeavors to introduce into the manufacture of sugar in the colonies; permit me to comment frankly upon the excess of duty which is levied upon white and clayed sugar.

I am, of course, ignorant of the reasons which influenced the administration in establishing the difference in the following duties which the sugars from our colonies, from America, for example, pay upon their entrance into France.

| | | | |
|---|---|---|---|
| Brown sugar..... | F. 45 00 | per 100 kilogrammes. | |
| Inferior white sugar ..... | 52 50 | " | " |
| Clayed sugar, of all shades.... | 66 50 | " | " |

It is probable that these differences (which, not being in proportion to the value of the sugars in the market, are almost equivalent to a prohibition upon the last two qualities) were established with the design of favoring both the shipping interest, by causing a more considerable weight of merchandise in the shape of brown sugar, and the metropolis, by giving to it exclusively the refining of this sugar.

But it seems certain that this measure was taken under the influence of old and erroneous convictions, which attributed to the colonial manufacture conditions of existence and stability different from those which it presents at this day.

If, however, colorless sugar cannot be produced from the cane, as was supposed a few years ago; if the molasses, which impregnates and colors this sugar, cannot be removed; if the production of colonial brown sugar must remain stationary as to quantity; if the quality cannot be improved, the excess of duty upon white sugar may, to a certain extent, be comprehended and justified.

But if, on the contrary, this coloration is the consequence of a bad mode of working; if it be demonstrated that the sugar which pre-exists in the cane is white; that it is obtained white, when a part is not destroyed; that the proportion extracted is, consequently, as much greater as it is less colored; what must be thought of a legislative measure which imposes upon that industry the exorbitant obligation of making small and bad products, and which places a barrier before one of the things which the laws should most respect—improvement?

It is demonstrated that, since this increase of the duty has been levied upon white and clayed sugars, the colonial manufacture, instead of following the natural tendency to improvement, has pursued a retrograde march; it is probable that this lamentable result is mainly owing to that excess of duty, although the colonists themselves do not render a very exact account of the wrong which this legislation has done them.

I find an argument in favor of this opinion in the concluding words of a note which I received from an experienced colonist, M. Jolliment de Marolles, and which relates to his practical observations upon the nature of cane juice.

"There can be no doubt that better results might be obtained if some of the new processes were adopted. Sixty years ago there was made, on several plantations, as beautiful sugar as it is possible to make, with the same apparatus as that now in use. These same plantations now produce sugar of a very ordinary quality, often, indeed, of a bad quality. The refiners who made that beauful sugar are dead."

It is certain that, in consequence of the measures adopted in legislation, the colonists are at this time under the sad necessity of making sugar of an inferior quality; for, if their sugar were beau-

tiful, it would be taxed with a duty which is prohibitory. Now, since we know that the quality reacts upon the quantity, the less beautiful the sugar is the less is the amount obtained.

Is refining, if it should still be prohibited to the colonists, necessary to the consumption of sugar? Cannot *brown* sugar be obtained sufficiently beautiful and good, that the consumer may be induced to buy it from the colonists without its passing through the refiner's pans?

Everybody knows, at this day, that refining is not indispensable to the production of white sugar. It is notorious, that at Bourbon M. Vincent has made brown sugar of a quality equal to the most beautiful refined sugar. To accomplish this remarkable result he has only borrowed from the manufacture of beet sugar its best methods of operation.

It is also known that the difficult problem of the direct transformation of crude beet sugar into refined sugar, without altering its form, a problem which was proposed a few years ago by the *Société d'encouragement*, is now realized. M. Boucher, a manufacturer of Pantin, near Paris, who obtained the prize, has sold, and continues to sell, a very large quantity of beet sugar purified in the very form which the evaporated juice has received, and purified in such a manner that it leaves this form with all the qualities of refined sugar.

The most remarkable thing about the method of M. Boucher is that there is nothing very peculiar in the process: it consists altogether in paying particular attention to every part of the operation; the concentrations being less colored than customary, much less molasses is obtained; the brown sugar resulting from these concentrations is immediately clayed, liquored, and stored.

M. Boucher says, moreover, that the beet yields him, by his process, eight tenths of the whole amount of sugar it contains.

It cannot be doubted that this improvement in the operations could be much more easily realized upon the cane than upon the beet; it would have the immediate consequence of producing a greater quantity of sugar, and of increasing the consumption—the cost of the white sugar being reduced by the almost total suppression of the expense of refining, and the profits of all the agents who are interposed between the producer and consumer.

But, in order to arrive at a result so desirable, it is necessary that the excess of duty levied upon white sugars be removed—it is necessary to leave to the manufacturer the right of improving. The shipping interest, so far from losing by this change, would, on the contrary, gain by it, probably very considerably, for it would soon transport more white sugar than it now receives of brown sugar; the refiners alone would find themselves aggrieved.

It would be well to examine whether the general interest does not demand that white sugar should receive an advantage over brown, in order to stimulate reasonable improvements in the colonial manufacture. However this may be, we must not lose sight of the following statistical numbers which express the condition,

present and future, more or less distant, of the industry of our colonies.

Bourbon, Guadaloupe, Martinique, and Cayenne, furnish at this time eighty million kilogrammes of sugar, which bring into the treasury forty millions of francs.

This quantity of sugar is produced by canes which contain, on an average, eighteen parts of sugar, and which yield seven parts at the farthest.*

Admitting that this yield may be extended to fourteen parts,† in consequence of the better application of methods already in use, our colonies would produce 160 million kilogrammes of sugar, and would bring into the treasury 80 millions of francs. The commerce would be doubled. This hypothesis supposes that the culture of the cane would not be augmented, and it is known how much it is at this time restrained and limited by the oppression under which the planters have been laboring for many years.

PARIS, *17th June*, 1842.

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NOTE D.

*Researches on the chemical composition of the sugar cane of Martinique, by M. Péligot.*

If the knowledge of the natural products, elaborated by chemical art, was always proportional to the industrial importance of the manufactured article, the study of the sugar cane, a plant upon which the commercial relations of the old and new world chiefly rest, would long ago have made known its physiological constitution, the quantity of sugar it contains, and how much it can be made to yield.

In our day, when a new chemical industry begins to develope itself, it commences by inquiring exactly what quantity of the substance can be extracted from the material upon which it operates. The successive improvements in the methods of extraction constantly tend to approach as near as possible, in practice, to the theoretical data furnished by science; and those arts which follow this course soon attain a high degree of perfection.

The manufacture of cane sugar has proceeded in a different manner; commenced at an epoch when science could not yet guide it, it has not sought latterly the amelioration which it might expect from a more perfect knowledge of the original materials with which it works. It has thus remained stationary for a long time; and if, of late years, it has received any improvements, it owes them to

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*Many well-informed persons admit that the number 5 represents the average yield of the cane of the colonies.

† This quantity (7 parts of 9) is certainly below what may be obtained practically. The beet, which contains two per cent. of foreign matter, which renders the extraction of its sugar much more difficult, and which does not exist in the cane, gives, by manufacturing processes, from 6 to 8 parts of sugar out of 10 or 12.

the intelligent efforts of a rival industry, which has surmounted with much perseverance the numerous obstacles opposed to its development.

Without discussing here the causes which have advanced the domestic manufacture of beet sugar beyond the colonial industry, we must admit that the most erroneous notions guide even now the manufacturer of cane sugar in his operations. It is, doubtless, to be regretted that we have not considered the justice, and moreover the policy of extending the necessary improvements to the colonists. If the government and the colonial councils had given to this old industry some of the encouragement, for improving its processes of extraction, which has never been wanting to the growing manufacture of beet sugar, the present complicated question as to the nature and qualities of the two sugars would likely never have arisen.

In order to demonstrate, in the clearest manner, how stationary and imperfect the theory of the manufacture of cane sugar has remained, permit me to give here a rapid analysis of the works, few at best, which treat of this subject. It will be seen that the most modern authors have repeated, without change, and accepted, without hesitation, the hypothetical views and the erroneous opinions which have been published more than fifty years. As to the practical part of that industry, the testimony of the colonists, and, above all, their commercial position, attest to us the great imperfection of the methods they employ in extracting sugar from the plant which, by its natural richness, should assure them an easy and prosperous support.

The oldest work written on this industry is, I believe, the essay on the art of cultivating the cane and of extracting the sugar from it, published in 1781, by De Cazaux, a member of the Royal Society of London. In this book the author, having especially in view the propagation of a new system of culture of the cane, gave but little attention to the chemical composition of the plant; however, he thus expresses himself in regard to the juice: "The knowledge of the parts which compose this juice, and of the proportions which they bear to each other in good canes, has served me as a rule to distinguish the bad, and to treat both according to their need; these parts are sugar and molasses, united in all kinds of juice to more or less acid, known by the name of fat, they require an agent to effect their separation—lime and ashes are acknowledged to be the most proper agents for this purpose."

He says, afterwards, that hitherto no one has formed any idea of the more or less intimate union of the fat with the sugar and molasses, and adds: "The usual proportion between the sugar and molasses in the young shoots, at least at the time when I fix for the harvest, appears to me to be very nearly equal weights; and the union of the fat with these parts in the common soil appears to me such that nothing is risked in trying, at the commencement of the season, pure lime, to the amount of four to six ounces on two hundred gallons of material, augmenting or diminishing after observing the effect of that quantity on the juice."

We see that at this epoch there was admitted, in the juice, the pre-existence of a weight of molasses equal to that of the sugar extracted from it; this error, which (except the proportions) still exists among the colonists, has been, without doubt, one of the principal causes of the imperfect state in which this industry remains. If, instead of considering molasses a natural and necessary product, De Cazaux had observed, or had formed the idea that its quantity is variable, and changes with the circumstances of the operations to which the juice is submitted; and if he had published the idea that molasses arises from the alteration which the sugar has undergone, this capital fact, confirmed elsewhere by the daily experience of the manufacturer, would have introduced such improvements, that the part which sugar plays as a principle of food would at this time be of incalculable importance, in consequence of its low price.

Dutrône la Couture, to whom the manufacturer of cane sugar is indebted for important improvements, published, in 1790, a treatise *on sugar cane and the art of extracting from it the essential salt.* "In this work he divides the juices of the cane into three kinds: 1st. A watery juice contained in the sap vessels, insipid, without odor and colorless, flowing in drops from the cut cane. 2d. A sweet mucous juice, enclosed in the pithy tissue, so thick as to escape only by the pressure produced by the cylinders. 3d. A juice contained in the proper vessels, (*vaisseaux propres,*) and particularly in the rind. The latter has a yellow color, a peculiar odor, and holds in solution a soapy extract. In addition to these three liquids, the pressure brought on the canes, in crushing their tissue, detaches some fibres which, according to the author, constitute two kinds of feculencies; the one, thick, coming from the rind; the other, very fluid, from the tissue of the pith. M. Dutrône, in the sixth chapter, insists much upon the properties of these two feculencies, upon the separation and the exact extraction of which all the operations of the sugar-house are based. He examines the action of heat, air, alcohol, and, above all, of lime and the fixed alkalies on these feculencies," &c. (Extract from the report, made, 31st May, 1788, to the Academy of Sciences, upon the manuscript work of Dutrône, by Darcet, F. de Boudaroy, Berthollet, and Fourcroy.)

Without delaying here to discuss the existence of the different products enumerated by Dutrône, I will simply state the fact that, in the first of his important memoirs on grape sugar, Proust reports some experiments which he made on the sugar cane of Malaga, and which, he thinks, confirm the opinions of Dutrône; but his opinion on the composition of the cane suffers a little perhaps from the necessity which was felt in 1806 of finding a substitute for cane sugar, which was then not to be found in our markets, in consequence of the continental blockade.

Having established, by examples, the existence of gum, extractive matter, and different acids in the fruits, this illustrious chemist expresses himself as follows:

"These facts, which deserve to be extended in the vegetable

kingdom, contribute more than ever to establish the existence of solid sugar and mucous sugar, which appear to be distributed in our fruits in extremely varied proportions.

"Liquid sugar, already designated by the compound name mucoso-sugar, because it was then considered as solid sugar rendered pasty by mucilage, has been well understood only since the time of Deyeux, who saw that this sugar was a species naturally liquid, and which must henceforth be placed on the list of immediate products.

"The work of Dutrône also confirms so clearly the existence of this product, by all the facts he has collected in his work, that it can no longer be supposed that the work of the sugar-house has any other design than the separation of the liquid from the crystallizable sugar. I will add here the results of the analyses I commenced of the sugar cane of Malaga.

"We find, in the freshly expressed juice, green feculencies, gum, extractive matter, malic acid, sulphate of lime, and the two kinds of sugar; all of which products are at least in their varieties nearly the same as those which are met with in the fruits."

Proust then gives the means which he employed to establish the presence of these different substances, and he has so little doubt of the pre-existence of part of the sugar in a liquid state, that he compares brown sugar to honey, and admits that "if the cultivation of the cane was possible in Europe, the whole product of the cane would not be subjected to the refining process, for one part would be consumed as molasses."

We are astonished to find all these opinions of Cazaux, Dutrône, and Proust admitted without dispute in the most modern work which treats of the sugar cane. It is an English treatise on the nature and properties of cane sugar, by Geo. Richardson Porter, published in London in 1830, and reprinted in Philadelphia in 1831. In his chapter on the composition of the juice of the cane, the author translates without scruple the chapter of Dutrône on this subject, and does not suspect that, in the space of fifty years, these opinions could be somewhat modified, in consequence of the progress of science and the chemical arts.

It was probably owing to this entire want of precise notions on the composition of sugar cane that Vauquelin was induced to import some cane juice from Martinique, in 1822, for the purpose of submitting it to analysis. Several attempts had already been made to send some of it to France, preserved in air-tight bottles, but it did not arrive in a suitable state of preservation for furnishing the information which was expected from its examination. The use of the process for preserving vegetable matter, due to Appert, gave Vauquelin the hope of attaining a better result; but his attempt was fruitless. "The juice sent from Martinique," says Vauquelin, "arrived in such an altered condition that it was no longer recognizable.* In some of the bottles the sugar was transformed into

*Annales de Chemie et de Physique, t. xx., p. 94.

carbonic acid, alcohol, and even into vinegar; in others, changed to a kind of semi-transparent gum, so thick that it flowed with difficulty from the vessels containing it." Thus Vauquelin, obliged to renounce the analysis of the juice, confined himself to the study of this peculiar and remarkable gummy substance, into which the sugar is transformed in consequence of this kind of fermentation.

About a year ago, when I published my analysis of beet sugar, M. Gradis, an intelligent merchant of Bordeaux, proposed to send for some canes and juice from Martinique, for the purpose of answering, by their examination, some questions which he submitted to me respecting the manufacture of sugar. He wished to know particularly if the method of washing and drying, which had been proposed for the fabrication of beet sugar, could be applied to the operations of the colonies. I accepted the obliging offer of M. Gradis with the more eagerness, inasmuch as I had desired, for a long time, to find an opportunity of comparing the composition of the cane and that of the beet, and to ascertain whether all the principles which had been admitted to exist in the juice of the cane were really there.

M. Gradis received and sent me, some months ago, eight bottles of cane juice and about three kilogrammes of canes which had been dried according to my directions by M. Peraud, an apothecary, of Martinique.

In spite of the alterations which the juice, sent to Vauquelin, had undergone, I designated the process of Appert as one which would insure the preservation of what was sent me; indeed, since this process has become common, and is employed on an immense scale, every day showing its efficacy more and more, even when applied to the most delicate articles of food, and those most liable to injury, it was very probable, if not certain, that being well executed it would maintain entire and unaltered a liquid which contained sugar, already in itself a preservative principle.

Thus, after having passed through the mill a certain quantity of fresh and beautiful canes, on the 12th April, the season of its full maturity, M. Peraud introduced into glass bottles the juice which he extracted from them, and which was the same as the juice of the sugar-house; he closed them carefully in the same manner as champagne is bottled; they were then placed in a water bath, the water of which was by degrees brought to the boiling point.

This simple preparation succeeded as well as could be desired, and the juice which reached me without having undergone any alteration I submitted to the inspection of several persons who had lived in the colonies, and they recognized in it all the characteristics of the ordinary juice.

It is a liquid having the balsamic odor of raw cane sugar, holding in suspension a greyish matter in a very divided state, which appears to be, or rather to have been, the globular matter existing in the expressed juices of almost all sweet vegetables. It is known that this matter is an active ferment, and that it causes the rapid alteration of those juices, after they have been kept for some time, either with or without the contact of the air. It appears to de-

monstrate that viscous fermentation, or the formation of the gummy product of the consistence of starch, which is engendered at the expense of the sugar in the juice of the cane and the beet, is developed under the influence of this same matter.

Now it is obvious that the use of Appert's process is particularly adapted for hindering the action of this body; since ferments are rendered inactive by the action of heat, and since the temperature of boiling water is more than sufficient for destroying their organization, or their vitality, if according to modern researches we consider them as vegetables. Thus, the juice of the cane which I received had remained unaltered, not only when it was tested, a short time after the opening of the vessel which contained it, but it kept several weeks without suffering any change whatever.

Its density, taken with precision, is 1,088, the density of water being 1,000. It indicates 11°.8 by Beaumé's hydrometer. It reddens litmus paper so slightly that its acidity may be regarded as almost nothing. To obtain it perfectly clear it is filtered through unsized paper, and is then of a very pale yellow color.

Under the persuasion I had in commencing the analysis, that it contained at least some of the numerous matters, in appreciable quantity, which had been recognized in it, I attempted in the first place to separate the sugar from those matters by the method which I have employed for determining the proportion of sugar which the beet contains. This method consists in treating with dilute alcohol a certain quantity of the mixture from which we wish to separate the sugar; decanting the alcohol holding the sugar in solution in preference to organic or mineral matters which accompany it; and in placing the liquor thus obtained under the receiver of an air pump, with a vessel containing quick lime. The latter, under the influence of the vacuum, absorbs only the aqueous vapor, so that at the end of several days the dilute alcohol is changed into absolute alcohol, and the sugar, which had been dissolved by means of the water combined with the alcohol, and which is insoluble in absolute alcohol, is gradually precipitated in a crystalline form, as the alcohol approaches its maximum degree of concentration.

But the examination of the juice soon showed me that processes yet more simple than that just mentioned sufficed to establish, if not its nature, at least the relative quantity of the substances of which it is composed; for, by evaporating over a fire a certain quantity of filtered juice, until it attains the consistency of syrup, we obtain at the end of several days a solid and crystalline residuum, the nature of which it is easy to recognize; this residuum is almost pure sugar.

Thus the whole analysis of the juice of the cane, at least in order to fix the total weight of the matters it holds in solution, consists in evaporating a determined quantity in a porcelain capsule, the weight of which we have first ascertained, then to weigh again this capsule when the solid mass which is formed ceases to diminish in weight by exposure in a vacuum or in dry air.

This same determination can be made in a more sure manner, if possible, and also by avoiding all intervention of heat. For this

purpose we evaporate under the receiver of an air pump a certain weight of juice; by means of the vacuum and concentrated sulphuric acid the liquid is transformed, after some time, into a thick syrup of a very yellow color, which obstinately refuses to crystallize or even to solidify; but, by diluting this syrupy product with a small quantity of alcohol, which is also evaporated in vacuo, we obtain rapidly a brittle crystalline mass which is then weighed easily in a state of perfect dryness.

This singular action of alcohol, which effects the solidification of the substances which, without it, would remain dissolved in water, appears to indicate the existence of a very small quantity of foreign matter in the sugar, which in the juice is coagulated and precipitated by the contact of the alcohol. We know how injurious the presence of vegetable albumen, gum, and the soluable salts is to the crystallization of sugar, even when these bodies, which the alcohol precipitates, are found in very small proportions relatively to the sugar. In my opinion it is wrong to admit the existence of a liquid uncrystallizable sugar as constituting a distinct variety. I think, and I hope to demonstrate in another work, that this pretended variety always results from the mixture of cane sugar or grape sugar with the gummy or saline matter, or else with the products of alteration which these two kinds of sugar suffer under numerous influences; the contact of these matters with the sugar prevents the total or partial crystallization of the latter body, according to the proportions of the mixtures.

Whatever may be the opinion, however, that we adopt on this subject, it is evident that the juice of the cane does not contain liquid sugar. By repeated analyses of the water and solid products it contains, using the two methods which I have just described, I found the juice to contain

| | |
|---|---|
| Solid matter | 21.3 |
| Water | 78.7 |
| | 100.0 |

The examination of the solid product which remains after separation from the water, leaves no doubt as to its nature; as I have said above, it is common raw sugar with all its recognized properties.

Nevertheless, the juice contains several other foreign matters, of which it is important to determine the nature and proportion. Proust observed, and the fact is necessarily exact, that the reagents which disclose the existence of the sulphates and chlorides, cause precipitates in the clear juice; the oxalate of ammonia shows in it the presence of lime; finally alcohol and the sub-acetate of lead demonstrate that it holds in solution some organic products.

But it was evident to me that the sum of these different substances is so small that it is useless if not impossible to determine the weight of each of them, especially by operating as I have done upon a small quantity of juice; I am also induced to think that

the authors who have written upon cane sugar have greatly exaggerated the importance of these matters and the injurious part which they play, according to them, in the operations which the juice of the cane is made to undergo for the extraction of its sugar. If Proust, for example, in place of devoting himself to the determination of their nature and their number, had first sought to ascertain their weight or the total weight which they have relatively to the sugar, he would have seen that there is no similarity to establish, as he pretended, between cane juice and the juice of the grape in relation to the foreign matters contained in these liquors.

There are, however, circumstances which may render the knowledge of the nature of these mineral and vegetable salts interesting. If, for example, it was required to enlighten the planter on the quality of his soil, on the comparative efficacy of his manures, &c., this appreciation of the salts, elaborated by the plant, would become useful and highly esteemed by him; but I have not the necessary elements for investigating these various questions.

I have determined, and in an approximate manner, on the sum of the mineral or fixed matters contained in the juice, by incinerating in a platinum capsule the residuum of the evaporation of a certain quantity of this liquid. Now, 170 cubic centimetres of juice, of the density 108.8, give 0.320 of white silicious ashes analogous to those which are obtained from the incineration of the grasses. In a second experiment, 300 cubic centimetres gave 0.550 of ashes, which gives 1.7 ashes for 1,000 of juice.*

I sought to determine approximatively the proportions of the vegetable substances, besides the sugar, which exist in solution in cane juice, by means of sub-acetate of lead, which we know precipitates almost all organic substances excepting sugar. By mixing the juice with a solution of sub-acetate of lead, a greenish deposite of a complex nature is found; 600 cubic centimetres of juice furnished 3.825 millegrammes of precipitate, brought to a state of perfect dryness. Now, as this precipitate leaves, by calcination, 62.1 per cent. of oxide of lead, we find, in starting from these data, that 1,000 parts of juice contain 2.3 parts of organic matter, susceptible of combining with the oxide of lead.

Then, by arranging the analytical results which I have just announced, we can represent the composition of the juice by the following numbers.†

| | |
|---|---|
| Sugar | 209.0 |
| Water | 771.7 (?) |
| Mineral salts | 17.0 (?) |
| Organic products | 2.3 |
| | 1,000.0 |

The juice of the cane, then, is nothing but sweet water, almost

*In the extract from this memoir, found in the *Comptes Rendus*, 1 per cent. is taken for 1 per 1,000.

† These numbers are erroneous; see note B, above.

pure, composed of one part sugar, and about four parts water. It is doubtless a result very unexpected, to the colonists especially, who have worked this plant so long, with the conviction that it contains, besides the non-crystallizable sugar, many mucous and gummy principles, &c. The existence of these different products is so generally admitted, that I can present only with doubt and hesitation the very simple results which I have obtained. Let me be permitted, however, to remark that, if they are inexact, the errors I have committed arise from circumstances difficult to appreciate.

Admitting, then, the authenticity of the materials sent me from Martinique, which is certified by the well known properties they present, as well as by the name of the person who sent them, cane sugar alters so easily, through numerous influences, depriving it of the property of crystallization, that if I had obtained, in my experiments, products foreign to the sugar, which were liquid and uncrystallizable, I should assuredly have been slow to admit its preexistence in the juice submitted to my examination. But, as the fact was otherwise, and the juice, after being preserved nearly a year, still yielded by simple evaporation, and without any particular treatment, almost all the solid matter as crystallizable sugar, my results, however new and singular they may appear, ought to merit a little credit, at least until an ulterior, and doubtless the next verification, annuls them, or ranks them with the number of facts positively acquired by science.

I do not, however, pretend to conclude, from these analyses, made on a single specimen, that the juice of the cane generally contains 21 per cent. of sugar. We know that this plant presents several distinct varieties, and that the juice often presents a density less than 11°.8 Beaumé. Its density, according to Dutrône, varies from 8° to 14° by the hydrometer.

The facts and opinions just developed, which, in my opinion, prove the exceedingly simple nature of the juice, must naturally be objected to when the daily experience of the sugar factories oppose their adoption. The juice which is there extracted is often thick, mucilaginous, and always yields uncrystallizable sugar or molasses. Whence come these products?

The answer to this question is easily made: they result from the alteration of the crystallizable sugar, which alone pre-exists originally in the cane.

It has been for a long time known that the beet, whose juice approaches most to that of the cane, does not contain the least quantity of uncrystallizable sugar, although a large proportion is always obtained in the operations to which the juice of the beet is submitted in the home manufacture. By analogy, we might presume that it ought to be the same with the juice of the cane, and with much more probability, as the sugar of this plant is much easier to extract than the sugar of the beet. My analyses tend to confirm this view.

Molasses is also produced by the alteration which the sugar undergoes in the operations to which the cane and the beet are sub-

mitted. Though all the improvements which have been made in the art of manufacturing sugar are intended to avoid or diminish this alteration, the causes from which it arises, it must be granted, are not yet well known or well appreciated. In another work, I shall develope the opinion which I have formed on this subject, in consequence of my researches on the chemical properties of sugar.

Yet, in spite of the insufficiency of exact observations on this point, which is so important in the making of sugar, every one agrees to attribute to two principal causes the formation of uncrystallizable sugar, or molasses. These causes are, 1st. The fermentation of the juice; and 2d. The ill-directed action of the heat during the evaporation of the water which it contains.

The vexatious rapidity with which, even in our climate, the expressed juices of sweet vegetables ferment is well known. It is also known, from incontestible experiments, that a sweet liquid becomes unfitted to furnish the sugar it contains, in the crystalline form, from the fact that it has commenced to ferment. Finally; I have made known in a preceding memoir the intense and rapid decomposing action which the alkalies, and lime particularly, exert on fruit sugar, originating under the influence of fermentation, and which is then transformed into the brown matter which colors molasses.

Now, the information which we possess of the colonial operations, induces the belief that the fermentation of cane juice, rendered so easy by the elevated temperature of the atmosphere, is for the manufacturer an ordinary and almost daily phenomenon. The juice, as it appears, becomes so frequently viscous and thick that we confound this accident, due to the production of that gummy matter mentioned by Vauquelin, with the natural character and normal properties belonging to the juice in a healthy state.

Moreover, the apparatus employed for receiving the expressed juice adds to the circumstances already too favorable for fermentation. The boiling apparatus generally adopted for the working of the cane is composed of several pans heated by one fire; the pan furthest from the fire is that which receives the juice as soon as it is taken from the mill, or the first reservoirs; it remains in this pan until it is evaporated to a certain level; then it passes into the second, where it is defecated by the lime; in the pan nearest the fire the boiling is finished.

As well as we can judge, at so great a distance, the arrangement of this apparatus and mode of operation seem very faulty. For it appears that the juice is submitted too long to a mean temperature of 30° to 40°, and this temperature tends to render still more active the fermentation which is already developed too easily.

But it is especially owing to the badly distributed action of the heat upon the juice that this system of apparatus is faulty; for the heat to which the juice is submitted is as much stronger as the juice becomes more concentrated. Now, as the sugar itself becomes as much more alterable by the fire, as it is dissolved in a less quantity of water, the conditions are fulfilled in such a manner as to burn or caramelize a considerable portion of sugar.

These bad arrangements, and above all the loss of the juice in crushing the canes, explains how it is that the sugar planter obtains, at the most, for 100 per cent. of cane, only from 8 to 6 per cent. of brown sugar and 2 to 3 of molasses, while the plant contains 18 per cent. of pure sugar.

Every one, then, must acknowledge that there are important improvements to be made in this industry. Without pretending that it is necessary to apply the boiling apparatus, more or less ingenious, which have been invented in France, nor even that it is necessary to renounce the direct action of the fire on the evaporating pans, I believe that a sensible increase in the yield of sugar would be obtained if the apparatus in use were arranged in the inverse order; by boiling the juice rapidly as soon as it leaves the mill the subsequent fermentation would be prevented; the fermenting principle being once destroyed, about 60° or 70°, it could be worked more slowly with perfect security. The well preserved juice used in my experiments had undergone no other preparation.

The juice, then, should pass first into the pan exposed to the immediate action of the heat, and placed over the fire; the defecated juice should pass successively into the others by following the inverse order to that now followed; the boiling should be terminated in the pan furthest from the fire. Such is the principle on which, it appears to me, the construction of the sugar-house apparatus should rest; as to the application of this principle, and the practical difficulties which it would present, they are not to be considered here.

I said above that M. Gradis, besides the juice just discussed, had sent me from Martinique, a few kilogrammes of canes dried in an oven at 60°. According to the note sent by him to me, M. Peraud obtained from 24 kilogrammes of fresh canes 7½ kilogrammes of dried canes. They contained, consequently, 68.7 per cent. of water. But their drying was not complete, for by exposing them in a stove at a temperature of 100 degrees cent., they still lost from 9 to 10 per cent. of water.

According to these data, fresh sugar cane consists of:

| | |
|---|---|
| Water | 72.0 |
| Solid matter | 28.0 |
| | 100.0 |

These numbers present only an approximation, since they are based on an experiment made in Martinique under circumstances which admitted of no great degree of precision; yet, the examination of these canes ought to furnish exact indications of the relative proportions of the sugar and the woody tissue which almost entirely compose the dry cane. On the other hand, having by the analysis of the juice the natural ratio existing between the water and the sugar in the canes from the same soil, I obtain, by combining these two analyses, the elements for establishing the composition of fresh cane.

Dried canes are composed of:

| | |
|---|---|
| Products soluble in water | 64.7 |
| Insoluble matter | 35.3 |
| | 100.0 |

These numbers were obtained by washing with warm water the dried canes cut afresh; we know that the insoluble product is formed of the woody structure of the plant; the analysis of the juice proves that the other part consists almost entirely of sugar.

The composition of the fresh cane, deduced from the preceding analysis and that of the juice which is the natural solution of these soluble products, is then expressed by the following numbers:

| | |
|---|---|
| Water | 72.1 |
| Sugar | 18.0 |
| Woody fibre | 9.9 |
| | 100.0 |

I suppress the weight of the organic and mineral salts which is too small to be of any account in an analysis of this kind.

I have just admitted that the dry canes contain 64.7 of soluble principle or sugar. I ought to offer some observations on the manner in which this result was obtained. By washing these canes with water, as I did, they lost 64.7 per cent. by weight; but by evaporating the solution it was impossible to obtain all the dissolved products in a state of crystallizable sugar; there always remained, on the contrary, a large proportion of liquid sugar. This alteration of a part of the sugar contained in the dried canes may be attributed to different causes; either they had been cut in too large pieces, or that the crowded tissue of the plant opposed the disengagement of the water by heat before the sugar had undergone a partial decomposition; or the drying had been made at an unequal temperature, too low or too high; it is certain that the soluble product which they furnish does not crystallize even under the same circumstances as the syrup.

The measures I have taken to establish the composition of fresh cane are not the less to be relied upon, since the examination of the juice shows that these 64.7 of soluable products were, if they are no longer crystallizable sugar.

The washing of these canes, evidently altered, is not, however, an operation easy to execute. I think that it cannot be done in the displacement apparatus analogous to those which serve, or which could serve for the levigation of the dry beet; the spongy and resisting condition of the tissue renders this operation profitless, at least, if the cane has not first been reduced to a fine powder. Without this condition, it is necessary to employ pressure, in order to obtain the sweet liquid which it has retained after a first washing with water.

These different circumstances, in my opinion, render deceitful the drying of cane as a new method for extracting sugar. I shall not

discuss here all the reasons which render the process of drying advantageous in certain cases for the beet, useless on the contrary, and perhaps hurtful to the sugar cane. But, as it has been in consideration latterly to send from the colonies dried canes, for the purpose of extracting the sugar from them in France, I have briefly advocated the principal causes which are opposed, in my opinion, to the economical treatment of this contemplated colonial commodity.

Fresh sugar cane, according to the preceding results, contains ninety per cent. of juice; this is not a new fact, but one to which the colonists have never attached the importance which it merits; it is certain, indeed, that the means which they employ for crushing the cane and extracting the juice from it are far from furnishing this quantity; it appears that the best constructed and most powerful mills give fifty per cent. of juice; in most factories the yield is less; there is obtained then, at the most, one-half of the product indicated by theory.

It is difficult to collect precise information on this subject, because it exacts an examination and attention which it is not customary to demand from the colonial industry. However, a pharmaceutist, of New Orleans, M. Avequin, who made some conscientious researches on sugar cane, (researches which I have not mentioned above, because they were made to confirm the ideas of Dutrone and Proust, on this plant; he finds seventeen different components, and admits that it contains uncrystallizable sugar.) M. Avequin, I say, has deemed it desirable to establish, by a series of experiments, the quantity of juice obtained in sugar houses.* According to him, one thousand parts of Otaheite cane passed through a first class mill, (West Point foundry,) gave 560 of juice and 440 of begassa—the mean of five experiments; one thousand parts of ribbon cane, passed through the same mill, yielded 472 of juice and 528 of begassa.

"Now," adds M. Avequin, "one thousand parts of cane contain 907 pounds of juice; then the loss in juice by working is 407, and is equivalent to a loss in sugar of 64.08. A planter who makes annually 300 hogsheads of sugar would obtain 544, if he could extract all the juice which the cane contains."

The harmony which exists between the results of M. Avequin and my own will be remarked for the proportions of the juice and the woody parts which the cane contains. It is then very evident that this important part of the colonial industry—the extraction of the juice, leaves much to be desired, by admitting even that the hard, and at the same time spongy tissue of the plant which prevents the crushing by mills more powerful still than those which are used, does not furnish a yield superior to that which is obtained; we could doubtless diminish the enormous loss which is experienced in the actual system, by plunging the begassa on leaving the mill into cold water, or, better still, into boiling water, and then press

* Journal de Chimie Médicale, Tome XII. page 132.

them a second time. Perhaps, also, drying in the sun, succeeded by methodical washings, could be used on the begassa already torn and dried by the crushing, to which it has once been submitted.

In short, we see how fruitful in profitable consequences the facts which precede are to the practice of the colonial sugar-houses. May they at last profit by the precepts which science has furnished them, and by the riches which nature has lavished on them. I do not hesitate to say, in conclusion, that, in my opinion, if the beet was cultivated in the colonies it would not furnish sugar by the processes which are employed there for working the sugar cane; and, if this last plant could exist in France, the quantity of sugar, which we know can be extracted from it, would soon reduce this aliment to a price accessible to all classes of the population.

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*Report on a memoir of M. E. Péligot, entitled "Researches on the chemical composition of the sugar cane of Martinique." Committee, MM. Robiquet, Pelouze, M. Thenard, reporter.*

At all times, researches, having for their object the exact determination of the different quantities of proximate principles in the sugar cane, would have fixed, in an especial manner, public attention; but now they acquire a new degree of interest from the circumstances by which we find ourselves surrounded.

M. Péligot, then, deserves praise for having undertaken them, the more so as he has rectified some errors very injurious to the important art of extracting sugar from the cane.

The authors who have been engaged in analysing cane juice regarded it as water holding in solution sugar, gum, albumen, mucilage, a kind of soapy matter, acids, and various salts; a liquid of a very complex nature. Hence arose the difficulty of extracting the sugar.

M. Péligot shows, on the contrary, that the filtered juice is formed of four parts of water and one part of crystallizable sugar; that it is only sweetened water, or at least that the saline or organic substances which we find in it are equivalent only to $\frac{1}{100}$ of its weight.

Then, seeking how much juice the cane contains, he found, with M. Avequin, that it contained 90 per cent.; but, as it contains one-fifth of sugar, it follows that the cane ought to contain 18 per cent., a quantity much greater than that heretofore admitted.

How does it happen that the manufacturers obtain only from six to eight per cent. of sugar, and three to two of molasses, for 100 per cent. of juice, and even, according to M. De Jabrun, a delegate from Guadaloupe, the yield of sugar is only four, and of molasses only 1.7? It is because the mill extracts only five-ninths of the juice, according to the information given to M. Peligot and M. Avequin, and only two-fifths according to M. De Jabrun.

In all cases it is now well established that a large quantity of sugar remains in the crushed cane, and is burnt with the begassa.

Would it not be possible to extract some from it by placing the crushed cane in contact with water near its boiling point?

On the other hand, it is certain (and all chemists agree to it) that the processes of evaporation and of boiling are very imperfect, and give rise to much molasses.

M. Péligot operated only on one quality of juice, and on one kind of cane which he owes to the kindness of M. Gradis, a merchant of Bordeaux. The juice, according to his direction, had been preserved by Appert's process, and the cane dried at 60°, by M. Péraud, a pharmaceutist, who had taken care to weigh it before and after the drying. The whole arrived in a state of perfect preservation.

Probably in operating on other canes and other juice results a little different would be arrived at.

However that may be, according to M. Péligot, the cane contains more sugar than we suppose.

A great quantity of sugar remains in the begassa.

The juice is, so to speak, only sugar and water.

The boiling of the juice is performed by very imperfect processes.

There is reason, then, to hope that important improvements will be made in the art of extracting the sugar from the cane, and that we shall thus be able to extract from it much more sugar than by the processes which have been used until now.

We think that the memoir of M. Péligot is worthy the approbation of the academy, and that it merits to be printed in the *Recuil des savans étrangers*.

The conclusions of this report are adopted.

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## NOTE E.

### *On the method by desiccation of Mr. Schutzenbach, and the yield of the cane in juice.*

In the third of the preceding reports I have repeatedly spoken unfavorably of the method by desiccation. (See art. 30, chap. 1, and arts. 9 and 18, chap. 2.) The following facts and views are, therefore, presented in order to do justice to this interesting subject.

Although the results of the industrial experiment, which was tried on a large scale in the island of Guadaloupe—of which I have been unable to obtain any authentic information beyond what is stated (see note C) by Mr. Péligot in his report to Admiral Duperré—have doubtless settled the question, whether dried pieces of cane can be exported from the West Indies, and sugar extracted from them profitably in Europe;* and although the ex-

* In the Sugar Planter's Manual, Dr. Evans says: "It was proposed a few years ago to cut the canes into thin slices, which were to be dried, either in the sun or by means of artifi-

periments of MM. Dupuy and Péligot, as well as my own, tend to show that dried cane is liable to rapid deterioration by fermentation, if kept for any length of time; still, there is a question well worthy of consideration, which may hereafter excite much attention, if it has not done so already, and which can only be decided by trial upon a manufacturing scale: can the method which Mr. Schutzenbach has introduced into the beet sugar industry, or some analagous process, be employed advantageously in the rival industry of the cane?

That method appears to have gone into operation in Germany to an extent which is, indeed, vast and astonishing. And it seems to be in the highest degree probable that the quantity of beet sugar produced on the continent of Europe will, by reason of this new method, become so great that the value of cane sugar may be considerably reduced. Doubtless, increased consumption and the recent pseudo-philanthropic liberation of negroes in the West Indies, will have a counteracting effect. Still, to obtain a larger amount of sugar from the same quantity and kind of canes, of better quality and at less cost of production, must, under any circumstances, be an object of chief importance to the American planter.

In Louisiana, the planters have to contend with such great disadvantages, that what might be perfectly practicable in Cuba, is impossible there. Some of these disadvantages are set forth so justly and forcibly by one of their number,* Mr. Valcour Aime, that I here quote his language: "Canes in Cuba ripen during fourteen or eighteen months, and require no ploughing, no ditching, and hardly any weeding; their rattoons last fifteen and twenty years. Here, after having tilled our soil in a manner that no farmer in the United States would be ashamed of, we must get sugar out of our canes, on an average, eight months after they have come out of the ground, and we must re-plant every second year. They grind six months in the year; we can hardly calculate on half that time to get through our crops, and must, therefore, manufacture our sugars twice as fast as they do theirs. With all these disadvantages on our side, and many more, which it would be too tedious to mention, our planters make fully as many pounds of sugar to the working hand as can be made in Cuba. This shows conclusively that we are not in the arrear, as Mr. McCulloh seems to think. There is no branch of industry in the United States for which more money is expended every year, in experiments, than for the sugar manufacture of Louisiana. If methods are adopted which may in many respects be considered faulty, it is not because our planters know no better, but because they are compelled by our climate to adopt the most expeditious means of operation.

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cial heat, and then forwarded to Europe for the purposes of manufacture. This scheme was tried in Guadaloupe, and, as might be imagined, failed. Decomposition of the canes commenced on board ship, and on arrival in France, the whole of their sugar was destroyed. Moreover, if they had arrived in a perfectly sound state, the trouble and expense attending the operation of slicing and drying, coupled with the additional freight, render it questionable whether the scheme would have been remunerative."

* See De Bow's Review, March, 1848, vol. 5, page 251.

The great question with us is not how to make the finest sugar and how to make the most of it, but how to make it fast enough; we know that frost may soon prevent us from making any at all. This is the reason which has prevented the planters of Louisiana from adopting generally the improved processes for making sugar; most of the ameliorated machinery operates too slowly to save our crops, and the perfected apparatus which are not liable to that fault, are within the reach of very few fortunes. Although, on account of our working more and better than the Cuba planters, we make as much sugar as they do."

To what extent these and other comparative disadvantages would operate to prevent the use of the method of desiccation in Louisiana no one can say positively, and experienced planters of that State alone must judge. Juice from canes of eight months' growth is much more impure than that of mature canes; and this difference of chemical composition would certainly give rise to corresponding differences in results, if trial were made of that method, in the West Indies and in Louisiana, under similar circumstances. Perfect similarity of circumstances would not be practicable, however, by reason of the difference of climate. Yet, in Louisiana, the low temperature of the winter months would tend to prevent fermentation, and thus in a measure compensate for the inferiority of the raw material. Experiments, upon a scale of sufficient magnitude to decide this question, without causing serious loss in any instance, might be tried by some of the planters; and the information thus obtained would certainly be highly interesting, if not important.

But if the method of desiccation be impracticable, or if, for any reason whatever, it be deemed inexpedient to modify the present mode of working very greatly, the question arises whether or not the yield of the cane cannot be much increased by some modification of the method of rolling.

In my third report I stated that "I have no authentic data from which I can determine the yield usually obtained in Louisiana." Since that statement was made, a valuable paper from the pen of J. P. Benjamin, esquire, appeared in De Bow's Review for January, 1848, from which I make the following extract:

"The first great object of the planter who is about to manufacture the crop, which forms the whole return for the labors of the year, is, undoubtedly, to extract from the cane all the juice that it contains. Unfortunately, no means have yet been devised by which this end can be completely obtained, and the begassa, as it leaves our best constructed mills, carries with it from one-third to one-fourth of the juice. However improbable it may appear, it is nevertheless certain, that the fluid contents of a cane form from 88 to 90 per cent. in weight of the entire structure of the stem, and I have taken some pains to ascertain during the present season the yield of juice from our mills of ordinary construction. I found the yield from the three-roller mill of average size, and run at a speed of 3½ revolutions per minute, to be sixty-one per cent.; whilst from another of very large size, of which the rollers were 5½ feet

in length and 28 inches in diameter, and which was run at a speed of only 2½ revolutions per minute, the yield was sixty-six per cent., the begassa being delivered from the latter almost pulverized and apparently dry. These results are undoubtedly much more satisfactory than would have been afforded some years ago, still, they show, that after all the care bestowed in raising our crops, from one-fourth to one-third of our produce is absolutely lost; and if we take what I believe to be a fair average of the yield of juice in sugars, that is, if we assume that one-tenth of the weight of the juice is the product in crystallized sugar, we find that we obtain only about 6½ per cent. of the weight of the cane in sugar, whereas chemical analysis shows that it contains 18 per cent."

Mr. Benjamin remarks, that "the very spongy consistency of the pith of the cane presents an obstacle to the extraction of all its juice by compression that is apparently insurmountable, and the very interesting inquiry at once suggests itself—are there no other means by which *all* the fluid contents of a cane can be obtained? That this can be done on a small scale in the laboratory is well known, but the difficulty is to effect the object on the large scale, and with the rapidity required on a plantation during the grinding season. A patent was taken out in England not long since, by a Mr. Michiel, for extracting the sugar from the cane by an entirely new process thus described and commented on in the Sugar Planters' Manual:"

"It consists in cutting the canes into extremely thin slices, and then submitting them to the action of a mixture of lime and water, which it is presumed will coagulate and render insoluble the whole of their nitrogenized constituents; thus permitting the extraction of the whole of the sugar with the soluble salts by means of water."

"*Were this process as practicable as its admirers seem to think, it ought, unquestionably, to be universally adopted; for I believe that were it skilfully carried out, almost the whole of the saccharine matter in the cane would to a certainty be extracted.* It remains, however, to be seen whether it is really so practicable, or whether its application will be sufficiently cheap. I much fear that the circular knives, by which the canes are to be sliced, if we may judge from what occurs in the slicing of the beet root, will be subject to continual derangement, and their edges blunted by the silicious coating of the cane. It may be doubted whether the operation will prove a sufficiently speedy one to admit of its adoption on large estates. The amount of evaporation demanded would also be great. This, it is true, may be obviated by placing the canes thus sliced in a succession of boxes having perforated bottoms, and placed one over the other in such a manner, that boiling water poured into the upper one will gradually percolate through each of the subjacent ones, and thus, by robbing the canes successively of the greater portion of their sugar, the saccharine liquid will become gradually more inspissated as it descends, until, when it comes away from the lowest box, it will have assumed the state of a syrup of considerable density."

To this quotation from Evans's excellent work Mr. Benjamin himself adds:

"Allow me to inform you that I have from reliable authority ascertained that the process of Michiel has actually been put in operation on a large scale in the island of Martinique, and with great success, and has there caused a yield of from 11 to 12 per cent. of the weight of the cane in sugar, on estates which had previously produced but six and a half per cent. I have not learned whether the maceration is with hot or cold water, nor whether if with the former the sugar is delinquescent by reason of the presence of pectine in the juice."

And after describing a proposed apparatus, consisting of a series of cisterns, for the systematic, continuous and complete extraction of the juice by maceration, as in the beet sugar industry, Mr. B. concludes:

That "if an apparatus on this or similar principles could be carried into operation on a large scale, a scale sufficient to take off the crop of the most extensive plantations, its results would be enormous; the whole sugar crop of the State would be at once doubled, and the inventor would reap the richest rewards for the time, labor and talent expended in perfecting it."

I may here observe, that lime converts pectine into a gelatinous but *insoluble* pectate of lime, by a peculiar transformation which Dumas and others have called pectic fermentation; in the use of the process of Michiel no trouble should, therefore, arise from the existence of pectine in the pulp of the cane.

At present, however, and until some such method as that of Michiel, or that of Schutzenbach, shall have become thoroughly tried and fully established, "it must be admitted," as Dr. Evans remarks, "that the only means which have been sufficiently tested to give us the confidence we have a right to demand, for obtaining the saccharine fluid from the cane, is the mill. We must, therefore, attempt to the utmost of our power to correct, at least in some measure, its present imperfections, or rather the imperfect results obtained by it."

All that this gentleman has written upon this subject is well worthy of the careful attention of every planter;* and the rules which he gives for rendering a mill as efficient as possible also deserve experimental trial. He says:

"In the island of Madeira I obtained at two different times by the same mill, and from canes of similar character and quality, 47.5 and 70.2 per cent. of juice. The mill was a small one, made at Aberdeen about two years previously, on the ordinary principle, with horizontal rollers, and the motive power was cattle. During the experiment, which furnished the last and largest result, the rollers were braced more than usually tight, and the number of canes introduced at a time were five or six, being the utmost that the strength of the cattle would admit of. The canes were squeezed

* See De Bow's Review, vol. 6, No. 4, October, 1848; in which periodical the reader will also find much valuable information on the sugar industry, etc.

once only; indeed, the begassa was too much lacerated to admit of its being passed between the rollers a second time with advantage."

For this reason Dr. Evans earnestly recommends that the mill be tightly braced, and that all possible pains be taken to render the pressure of the canes as complete as possible, by avoiding all irregularity both in feeding the mill and in its motion, etc., etc. He correctly argues that the sugar left in the begassa is a dead loss, even as fuel, because fermentation promptly takes place and converts it either into incombustible substances, lactic acid, etc., or into carbonic acid, etc., which are volatile; so that when used the woody fibre alone remains. He recommends the use of the begassa as manure, that it may increase the crop, its value in the West Indies being 50 per cent. greater, in his opinion, if thus employed, than if used as fuel in place of coal imported at five dollars per ton. He shows the importance of increasing the yield in juice by the calculation; that if the amount be augmented only from 50 to 60 per cent. on an estate making 200 tons of sugar, the annual crop would then give 240 tons. And if the begassa be used entirely for manure, so that it shall become necessary to purchase coal at five dollars per ton, then assuming the value of the 40 additional tons of sugar to be $100 per ton, and the quantity of coal required to be 240 tons, there would be a clear gain of $2,800. The gain would, of course, be greater if the begassa is not needed for manure, and if used in place of a portion of the coal. Finally, Dr. Evans speaks of mills with five or four rollers, as follows:

"Mills have been within the last few years manufactured with five rollers, which are placed with regard to each other, in the same manner as are the three rollers in the usual horizontal mills —that is, two are placed above and three below. Mills thus constructed have been successfully used in Cuba, Bourbon, and the Mauritius, 70 per cent. of juice having been obtained by them at one operation, without much greater laceration of the begassa than is usually produced by the three-roller mill. But, as might be foreseen, a great objection has been raised against them, owing to the very considerable increase of motive power which they require."

"Latterly, sugar-mills have been constructed with four rollers, which are placed two below, and the other two above, and immediately over the former. These mills have been greatly extolled, producing, as it is said, from 70 to 75 lbs. of juice from 100 lbs. of canes, with a motive power little, if any, greater than that which is required by an ordinary three-roller mill of equal size. I have not seen mills of this construction in operation, but I believe that the advantages which they are said to possess have not been exaggerated."

Upon this subject, P. M. Lapice, esq., of Louisiana, informs me, through a mutual friend, that a double pressure mill, which has been erected upon his plantation, "extracts nearly all the juice from the cane, and fits the begassa in the best possible manner for manure, which is fit for immediate use."

In conclusion, I present to the reader the following account of

Mr. Shutzenbach's method by desiccation, extracted from the *Bulletin de la Societe d'Encouragement pour l'industrie nationale*, of Paris, for the years 1838 and 1846; first remarking, however, that the assertion made by me in my third report, that "double the amount of water has to be evaporated," (see art. 9, § 1, chap. 2,) is not correct; for, since the dried cane furnishes a saccharine solution of 30° Baumé, it follows that *the only additional* quantity of water to be evaporated is that contained by such a solution, over and above the proportion which is to be permitted to remain in the syrup when concentrated to the striking point.

The beets after being cleaned in the ordinary manner, by scraping and washing, are cut into small parallelopipeds, by means of a very simple and economical machine, consisting of a peculiar knife, set in a frame, to which a vertical reciprocating motion is imparted by a connecting rod and eccentric; a full description of which, with detailed drawings, is given in the *Bull. de la Soc. d'Encour.*, 1838, *page* 438. The form thus given to the pieces of beet is considered by Mr. Schutzenback the best adapted for complete desiccation.

They are next conveyed to the stove to be dried. For this purpose he describes two different arrangements; one, a cast iron furnace, or large stove, surmounted by a sheet-iron pipe, bent in the form of a serpentine or coil, the whole being closely surrounded by a brick wall, through which holes, furnished with dampers, admit the air to be heated in greater or less quantity. A thin sheet-iron plate, pierced with numerous holes, extends over this furnace to distribute the heat uniformly; and the beets to be dried are placed above in trays with bottoms of wire gauze, which are supported by frame work. (See pages 439–'40, and plate 750 of the said volume.) The other arrangement, which is preferred by Mr. Schutzenbach, consists of a rather complicated furnace for heating air, by means of vertical pipes passing through the flue, which extends horizontally the entire length of the building, and of an endless band of wire gauze moved upon pullies by a steam engine, by which the pieces of beet are conveyed backward and forward many times in the ascending current of hot air, the circulation of which is rendered more rapid by the action of a ventilator or blowing machine. (See pages 440–'41, and plate 749.) The whole is enclosed between walls of masonry, and an extended plate of sheet-iron, pierced with numerous orifices, distributes the heated air uniformly, and catches any pieces of beet which may happen to fall.

"To this furnace Mr. Schutzenbach attributes the following advantages: 1st. Great saving of manual labor. 2d. In the continuous movement of the metallic band every surface of the pieces of beet is brought into contact with the heated air. 3d. Security against accident by fire. 4th. The heated air and vapor which escapes may be used for warming other parts of the establishment. 5th. The desiccation of beets is performed continuously and upon a large scale."

"The process followed by Mr. Schutzenbach for extracting the sugar from the dried beets is as follows:"

"Coming from the stove perfectly dry, they are reduced to powder in any manner; and the sugar is then extracted from this powder by macerating it in water acidulated with sulphuric acid. For this purpose, nine parts, by weight, of pure water are poured into a wooden tub, and from two-thirds to three-quarters (according to the richness of the beets) of a per cent. of the sulphuric acid of commerce is then added; four parts, by weight, of powdered beet are stirred into the liquid, and the stirring is continued uninterruptedly until the acid is absorbed. After repose, the precipitated pulp is removed, and the liquid it retains is expressed in the usual manner."

"The juice thus obtained is reserved for after treatment. The residue contained in the sacks is macerated in water acidulated to the same degree, and then pressed anew. The juice resulting from this second pressure is used in place of water for dissolving a fresh portion of powdered beet; and the same operation is repeated until the pulp appears to be entirely exhausted of saccharine matter."

"The expressed juice, of the required density, is mixed, at a low temperature, with as much lime in powder as is necessary to neutralize the acid; and the calcareous precipitate is then removed by the ordinary means. The albumen and tannin contained in the beet, being united with the fibrous portion by desiccation, do not escape with the juice, so that it is transparent even before filtration."

"It is afterwards treated in the usual manner to obtain the crystalline sugar; only a smaller quantity of animal charcoal is used in clarification than is requisite for the juice from beets which have not been dried."

At the meeting of the *Societe d' Encouragement*, March 18, 1846, the president (M. Dumas) "announced that several manufacturers of beet sugar from the *department du Nord* and from Germany were present, whom he invited to communicate to the society any information, in relation to an industry, which is an object of its constant solicitude. That the importance of such communications might be fully appreciated, the president described the present situation of the sugar industry." * * * * *

"The president announced that important communications have been made to the society upon the employment of desiccation."

"It is known, said he, that the manufacture of beet sugar is carried on in two principal methods. In the one, the root is subjected to the action of rasps, the pulp pressed, the juice treated with lime and then evaporated to obtain the sugar. In the other the root is cut into small pieces and then dried, (thus prepared, it keeps a long time without alteration;) it is washed, and the syrup obtained is evaporated to extract the sugar which it contains."

"The process of desiccation invented by Mr. Schutzenbach, and of which a detailed description, accompanied by figures, is given in the *Bulletin* of the society, page 438, for the year 1838, has made but little progress in France. Yet, it furnishes sugars of better quality and greater quantity; the work can be continued longer; the requisite capital is less; and the cultivation of the beets may

be carried on at a distance from the factory, for the reason that the weight may be reduced four-fifths."

"M. de Haber, who has worked according to this method for a long time in the grand duchy of Baden, communicated the results obtained in that country, as well as in the kingdom of Wurtemberg."

"The principal factory is established at Waghaeusel, near Manheim. It has operated this year (1845) upon 30 millions of kilogrammes of beets. In the next year (1846) it will operate upon 50 millions of kilogrammes."

"The *tourailles* or stoves have 21 square metres of surface; 30 kilogrammes for every 0.105 square metres are dried in 24 hours. The beet loses 80 to 84 per cent. of its weight by the evaporation."

"To work the *cossette*, (dried beet,) it is ground in a mill. A single filtration is sufficient to deprive it of its sugar. The syrup obtained is perfectly clear, marking 20° to 25° Baumé, and containing 40 to 42 per cent. of sugar; whereas the juice obtained from fresh pulp, which marks only 7° to 8° Baumé, contains but 10 per cent."

"Hence, to obtain 40 parts of sugar by the old method, 360 parts of water must be evaporated, or six times as much as is requisite to evaporate the syrup obtained by the new process. In the concentration, the fuel which has served for dessication is, therefore, economized."

"The expenses of manufacture are considerably reduced; the rasps and presses are dispensed with; the sacks and trays are replaced by less costly muslin filters."

"The diminution of the expense of the establishment is not less worthy of attention. The dried beet occupies only the fifth of the volume it had when fresh. M. de Haber estimates the quantity of sugar, which can be made in the same place and with the same apparatus, as 15 to 18 times as much as by the old method."

"M. Evrard, a manufacturer of beet sugar at Valenciennes, then addressed the society as follows:

"The work by dessication in the factory d'Herin has completely satisfied us. The *cossette* obtained is white; it keeps perfectly in the storehouse, and even in a deep barn. The portions which touch the walls alone being slightly softened, but they are neither mouldy nor of an unpleasant ordor."

"One hundred kilogrammes of fresh beets yield 18 of *cossette*. To dry 40,000 kilogrammes of beets, it requires:

| | |
|---|---|
| "40 hectolitres of coal, at 1.5 francs ..... | 60 francs. |
| 20 days' work, (of women,) at 0.80..... | 16 " |
| 14 do. (of men,) at 1.50..... | 21 " |
| 90 days' interest on 14,000 francs, (the cost of the stoves,) at 7 per cent..... | 11 " |
| Total..... | 108 francs. |

"One hundred kilogrammes of *cossette* cost 11 francs and 11 centimes.

"The maceration is performed in the apparatus of M. Duquesne, which is closed hermetically; two causes of fermentation are thus avoided—the contact of the air, and the cooling of the pulp. M. Evrard has repeatedly extracted all the sugar from the *cossette* without the addition of lime, and never observed the slightest trace of fermentation. Yet, to avoid the abundant deposites which would obstruct the establishment if lime were added to the juice to neutralize and defecate it, he has been obliged to defecate the juice in the *cossette*, by treating it directly with lime. The pulp afterwards contains no caustic lime, and answers for feeding cattle."

"He then gave the following numerical results: 350 kilogrammes of *cossette*, corresponding to 925 kilogrammes of fresh beets, yield 11 hectolitres of juice at 9° Baumé. The charge is 100 kilogrammes of sugar of the type, or 5.2 per cent., reckoning 1,400 grains to the degree. The quantity of sugar, *bonne quatrieme*, is 7 per cent. in the first juice. Taking this as the absolute yield, we get the remarkable result that 100 kilogrammes of *cossette* contain 38 kilogrammes of sugar, at the price 11 francs 11 centimes, or 29 francs 73 centimes per 100 kilogrammes."

"The advantages of the new method for the manufacture of sugar appear incontestable. Yet, it is probable that the establishments which are properous under the present system will find it difficult to decide upon a change of their mode of working; for this reason, M. Evrard proposes a mixed system, which will convince them fully of the fitness of suppressing the rasps and presses."

"It consists in adding to the juice to be defecated, by means of dried beets, brown sugar at 29 francs 23 centimes per 100 kilogrammes, weighing 25° Baumé. The molasses will go to the manufacturer."

"Brown sugar costs, at present, 72 francs per 70 kilogrammes; there is, therefore, nothing to be gained by purchasing it."

"The president tendered to MM. de Haber and Evrard the thanks of the society for their interesting communications."

"Upon this occasion he deemed it proper to present to the society some information which he had himself received."

"An immense establishment has just been constructed by Mr. Schutzenbach, in Gallicia, at the foot of the Karpathian mountains, at fifty leagues from Lemberg; it can produce at least twenty millions of refined sugar per annum, and is composed of a central sugar house, and fourteen drying houses around the former, within a circle of seven or eight leagues."

"The beets cultivated in the vicinity of each drying house are dried in vast stores; they have a cossette which contains nearly one half of its weight of sugar—100 kilogrammes reduced to 20 by desication."

"Transported to the central factory, the cossette is there washed in close vessels, and gives a syrup which attains at once to 30° Baumé; this, by evaporation in open pans, yields directly refined sugar."

"Calculated from the weight of the fresh beets, the amount of this sugar is 6 per cent."

"What is to be remarked, is the fact that the vacuum pan is not used for evaporation. Mr. Schutzenbach has not wished to make use of it in a country poor in mechanical resources; he has succeeded, favored by the nature of the beets, which are probably cultivated in lands much less manured than ours."

"Mr. Schutzenbach has established his central sugar factory in a vast building, 133 metres (432 feet) long by 27 metres (86 feet) wide, covered by a roof of iron. He estimates that the cost of this establishment, with its annexed appurtenances, does not amount to one-sixth of what would have been necessary to attain the same results by the old processes."

"The society should behold with pleasure that a process, the high value of which it was the first to proclaim, and which it has sought by every means to introduce and render popular in France, fully realizes its hopes." * * * * * *

"When we see real colonies thus springing up in Europe itself, by virtue of these new methods, we feel that the sugar industry, thus regarded, constitutes a new social progress."

"Let the society then continue to encourage the erection of sugar factories, based upon the method of desiccation, and drying houses, in every village, which shall dry the beets cultivated in the vicinity, so as to permit them to be kept without injury, as well as to be transported to a distance. It is evident that the culture of the beet would thus become general, and not confined to a few favored localities; this vegetable would become a regular crop, and assume its place in the combinations of agriculture instead of being replanted every year in the same ground, and for a long series of years. The whole country would then profit by the advantages which its culture brings with it, and the soil would certainly be improved." * * * * "Notwithstanding the vicissitudes which this process has undergone in France, and those which may yet threaten it, I have never varied in my opinion of it, as is well known to you, and I am confident that the name of *Schutzenbach* will hereafter be inscribed among those of the rare and courageous men who have introduced into the world ideas useful to the human race."

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NOTE F.

*Remarks and criticisms by Mr. Valcour Aime.*

In De Bow's Review, vol. 5, page 254, Mr. Valcour Aime criticizes the statement repeated by me in article 39, page 65, that "excellent sugar was said to have been made in 1845–'6, by Messrs. Packwood, Benjamin and V. Degruy, by the use of Rillieux's apparatus, from acid frosted cane juice, which by the ordinary method would, it is stated, have yielded molasses only." For that statement I am not responsible; it was based upon the report of the committee of the Agriculturists' and Mechanics' Association of Louisiana, and

the letter of V. Degruy, esq., therein contained, which report I considered worthy of credit, by reason of the source from which it came, and embodied it in my work. I have no knowledge upon the subject, and if the committee have erred, there is, perhaps, no one who can with more propriety assume to correct them than Mr. Valcour Aime himself, who is not only entitled to speak with authority as a planter of long experience, but also well known throughout the State.

The following are Mr. V. Aime's remarks: "It is true that fair sugar can be extracted from frosted canes, by means of boneblack filters and the vacuum pan, when only a very inferior article could be obtained by the common method. The canes, when frost bitten, can thus be rendered profitable for a few days longer. This is not, however, the peculiar advantage of Rillieux's process; the same result can be obtained by means of Howard's, Roth's, Derosne's, or any other system for evaporating in vacuo. I have seen at Mr. Lapice's, sugar of good color and grain, made by Derosne's apparatus which was so very sour as to excite a disagreeable sensation on the tongue; when the sugar was drained the acidity disappeared, because it was confined to the uncrystallized part. But after the deterioration of the canes has so far progressed that the juice, when boiled in open pans, produces in the battery or teache nothing but a viscous syrup of fine yellow color, from which, by the common process, not a particle of grain can be obtained, I contend that no apparatus can crystallize it. In the winter of 1845–'6, the pneumatic pans or tigers constructed by Rillieux on Messrs. Benjamin and Packwood's plantation having completely failed, those gentlemen, to save their canes, had to work the whole of their crop into syrup, which, afterwards, was manufactured at Mr. Oxnard's refinery. I have there seen in that refinery syrup manufactured from frosted canes by Rillieux's apparatus, from which nothing could be made; other syrup coming from canes less deteriorated, produced sugar resembling common wax, while all the syrup obtained by the same means, previous to the canes being frosted, or before the juice was quite altered after the frost, has produced in the same year and at the same refinery sugar of the very first quality. It is much to be regretted that Mr. McCulloh had no opportunity for examining the phenomena which present themselves successively during the process of the fermentation of our cane juice. I have seen nowhere clearly explained why frosted cane juice, from which good sugar can be produced for several days, even when sourness is quite peceptible to the taste, ceases to granulate, sometimes in the space of a very few hours. In the paragraph quoted above, the Professor seems to intimate that acids of different kinds may be generated in the course of fermentation, and he is probably right. I am no chemist, but I have learnt from one who has turned much of his attention to the manufacture of Louisiana sugar, that whilst there are acids, such as the hydrochloric, the lactic, the citric, &c., which prevent granulation, the acetic acid is so far from acting against it that some confecticners use vinegar to aid the crystallization of rock candy."

. Concerning the last sentence of the above extract, I may, perhaps, be permitted to remark, that acids generally injure sugar in solution, by converting it into *chylariose*, or left polarizing liquid sugar, which cannot be crystallized. Acetic acid, however, does not possess this inverting power; or, at least, it acts very slowly and very feebly, if at all. Yet I am not aware that it is used by the confectioners to *aid* crystallization, which I consider very doubtful; though I know they employ it to retard the molecular change, which destroys the transparency of candy or barley sugar. M. Péligot states that both lactic and acetic acids exert no injurious influence upon crystallizable sugar; and he thence concludes that when cane juice becomes acid by either the viscous or the alcoholic fermentation, the acidity is *not a cause but a consequence* of the transformation which the sugar undergoes, or rather has, already, in part undergone. According to H. Rose, a celebrated chemist of Germany, the presence of a vegetable acid causes alcoholic fermentation to progress *more* rapidly, though it is not the fermenting agent; cream of tartar has long been known to operate in a similar manner.

Mr. Valcour Aime does not, in my opinion, overate the importance of the phenomena of fermentation, in relation to the cane sugar industry. It must be admitted that little or nothing is known accurately upon the subject of the chemical changes which cane juice suffers under various circumstances. Chemists have investigated carefully the transformations of pure saccharine solutions; and the knowledge thus obtained may be *hypothetically* applied to the juice of the cane, but such slight influences operate so powerfully upon the phenomena of fermentation; and different ferments produce such different results, that until the spontaneous transformations of the cane and its juice have been thoroughly investigated, we can *only speculate* upon the subject.

In the same review, from which I have made the foregoing extract, Mr. Valcour Aime does me the honor to express a regret that I had not full opportunity of becoming acquainted with the sugar industry of Louisiana, so that I might have "done to the old sugar planters of the country that justice which they certainly would have obtained from him (me) if he had known more about them." I have elsewhere (see De Bow's review, October 1848, vol. 6, page 354,) stated that "if in anything I may have said I have done injustice to the planters of Louisiana, individually or collectively, it has been solely from want of information." That declaration I now repeat, with the assurance that I will take pleasure in correcting any errors I may have committed, as I have endeavored to do in this reprint, in every instance of which I was apprized of their existence by the criticisms of Mr. V. Aime and others.

It is, perhaps, due to Mr. V. Aime that I should here insert his account of his own contributions to the industry of the State; which account was elicited by my having ascribed to Messrs. Benjamin and Packwood "the merit of having first made directly from a vegetable juice sugar of absolute chemical purity, combined with

perfection of crystal and color." I may state that, in 1845, the Franklin Institute, of Pennsylvania, awarded a medal to Jos. S. Lovering & Co., for obtaining the same end, (chemical purity, with perfection of crystal and color,) upon a large scale in refining sugar. And Mr. V. Aime will, doubtless, concur with me in the opinion that Messrs. Benjamin and Packwood are not the less entitled to praise, for their success, by reason of the fact that he also may have accomplished the same result. With these observations, I give Mr. V. Aime's account, and I do so with the greater pleasure because I have embodied in my report the critical remarks of the committee of the Agricultural and Mechanics' Association, concerning his improvements, and because it also contains information which is both interesting and valuable.

He says: "I am so far from being disposed to detract anything from the merit of Messrs. Benjamin and Packwood, that I would not have the least objection to their being represented as having originated a most important improvement in the manufacture of sugar, if the old planters of the State were not thereby cast rather too much in the shade. The stay of Mr. McCulloh in the State was, as I observed before, so very short that he had no time to become well acquainted with the former situation of our sugar industry, and the various successful steps that have been taken to improve it. It is no doubt on that account that he has in the different parts of his report alluded somewhat unfavorably to our improvements."

"It is not of late years only that white sugars, derived from the cane juice, have been made with more or less success in Louisiana. As far as I can remember, and I am no longer a young man, I recollect to have seen white clayed sugar made on many of our plantations, for home consumption at least, by the same operation which, in Cuba, is carried on on a large scale. Another grade of sugar was made about eighteen years ago by Mr. T. Morgan, who, as the report correctly states, was the first to introduce the vacuum pan in this country for the evaporation of cane juice. A few years afterwards he obtained by liquoring in moulds, without the use of bag filters, good white sugar. Neither filters nor defecators were employed in connexion with Rillieux's apparatus, when Mr. Packwood, in the winter of 1843–'4, made with it about thirty hogsheads of sugar. In the succeeding season defecators and bone black filters having been added to the same apparatus, prime brown sugar was obtained, without any refining process, on the same estate. The specimen of sugar so highly eulogized by the report was produced in the winter of 1846–'7, on Messrs. Benjamin and Packwood's plantation, by using Rillieux's perfected apparatus, and liquoring the sugar in tigers."

"Although it may look like egotism for me to say so, yet I cannot avoid remarking that since 1834 I have been making clarified, stamp, and loaf sugar, directly from a *vegetable juice*, and that since 1840, when I first used bone black filters, my sugar has been at least equal in quality, as well as perfection of crystal and color,

to that manufactured in 1846–'7, by Messrs. Benjamin and Packwood."

"As it may not be uninteresting to be informed of the different trials of one who has some claim to be considered here as the pioneer in refining sugar from the cane juice, permit me to state that, after having attempted, without success, some expensive experiments for making white sugar in 1830, I tried, in connexion with a common set of kettles, in 1832, the bascule pan, and in 1833 the serpentine tub, and ascertained that, with good canes, no definite advantage can be derived from either. In 1834 I bought moulds, procured the bag filters of Taylor to filter my cane juice when boiled in the common kettles to 30° Baumé, ordered from London one of Howard's vacuum pans, from the old makers, William Oaks & Son, and began to refine. It would be too tedious to detail the trouble I experienced and the accidents and mistakes from which I had to suffer during that winter; I was so much annoyed that I would certainly have given up my experience, at least for that year, if my sugar-house had not been so altered as to put it out of my power to proceed by the common method. I had to refine or lose my canes. The final result was upon the whole satisfactory, and I not only got through my crop of 340,000 pounds, but bought some inferior sugars from the neighborhood, which I also refined. I obtained 12 cents a pound for my loaf sugar, which was of course inferior to what I make now, since I used no bone black. From 1834 to 1839 inclusive, every one of my crops were worked in the same way, with the only difference that the experience acquired with every additional year, enabling me to understand better how a refinery ought to be conducted, I increased mine and managed it more conveniently. Having heard in 1840 of the filter Peyron, represented as working continuously, and without renewing the bone black, I sent my boiler to Europe, at an expense of eight or nine hundred dollars, to examine and procure it, if found to answer. He came back in time for the crop, not with Peyron's filter, however, but with another on Dumont's plan, which is employed in England. The syrup of that year being first filtered in the bags and passed afterwards over bone black, produced sugar which was fully worth two cents more than that I had previously made. I effected no other important change in my refinery until 1845, when I procured Derosne's apparatus, with some modifications in the pans and distributions. On account of the air pump having been made too weak, I could manufacture but a small part of the crop of that year, but in the succeeding season I used nothing else, and have since that time ceased to boil my syrup in open kettles. I find that I make by that means still better sugars; although, on account of the quantity now produced, not only in this State, but in the north and west, I get much less money for it."

"In the year 1846, Mr. Lapice put up one of Derosne's apparatus, which was, like mine, made at the Novelty Works, New York."

"The main difference which can be found between the means employed by me since 1840 for refining, and those Messrs. Benjamin and Packwood used in 1846, consist in this: that those gentle-

men liquor their sugars in tigers, while I do so in moulds; but this difference can, of course, create none either in the quality or beauty of the sugars. The only question to be raised between the two processes is one of economy and of time; in this, practical men may differ. In 1845, after examining, in company with Mr. Lapice, tigers on the plan of those since constructed by Messrs. Benjamin and Packwood, which we found in the refinery of Mr. Adams, near Matanzas, in Cuba, I determined to keep to my moulds, and Mr. Lapice came to a different conclusion. He had tigers made, which worked well in 1846, and he has used them successfully ever since. They can undoubtedly be considered as a valuable improvement, which may be rendered as profitable here as it has been for a great many years in the West India islands. Sugars may, by that means, be sooner prepared for market, and on that account those who have to put up new establishments for refining ought probably to adopt tigers in preference to moulds; but I do not think that the advantage to be derived from them is sufficiently great to induce those who are already provided with moulds to give them up."

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NOTE G.

*On the chemical composition of the calcareous sediment which forms in the evaporating pans.*

In the first edition of my report, at page 69, I said of the calcareous deposite, or sediment, which forms upon the bottoms of the sugar pans—

"This deposite has been analyzed by M. Avequin in New Orleans, with the following results:

| | |
|---|---|
| Sub-phosphate of lime | 92.5 |
| Carbonate of lime | 1.4 |
| Silica | 4.7 |
| Phosphate of copper | 1.4 |
| | 100.0 |

"Mr. Reynolds obtained somewhat similar results from a specimen procured by me from the battery kettle upon the Saratoga sugar estate of Drake, Brothers, & Co., in the island of Cuba; the analysis of which was as follows:

| | |
|---|---|
| Organic matter and water | 54.72 |
| Sub-phosphate of lime | 11.90 |
| Carbonate of lime | 33.25 |
| Silica | 0.13 |
| Oxide of iron | trace |
| | 100.00 |

Both of these analyses are erroneous. The first was correctly copied from M. Dumas's Treatise on Chemistry Applied to the Arts, vol. 6, page 220, but does not correspond with that given by M. Avequin in his original memoir, contained in the Journal de Pharmacie, vol. 27, page 15, in which it is stated that 1,000 grammes, by combustion in a Hessian crucible for 24 hours, left a residue of 492 grammes, and had, therefore, lost 50.8 per cent. of organic matter. M. Avequin did not determine the quantity of carbonic acid which this residue contained, and which he says escaped with effervescence when he undertook to dissolve 100 grammes thereof in nitric acid. It must have been considerable; and his whole examination is, as M. Péligot has stated,* very imperfect and unsatisfactory.

Believing the large proportion of sub-phosphate of lime given by M. Avequin (92.5 per cent. of the residual 492 grammes) to be very improbable, and doubting the correctness of even the 11.9 per cent. of Mr. Reynolds's results, I was induced to inquire of the latter gentleman whether he was certain of its accuracy. In reply he informed me that he had not preserved the original memorandum of his work, and that he could not, after so long a time, speak with certainty concerning its details; also that he did not place entire confidence in them, because he remembered that the analysis was made hastily. He kindly offered, at the same time, to repeat his examination of the substance, (of which I still possess a considerable quantity,) and the following is his account of its analysis:

"PHILADELPHIA, *December* 4, 1848.

"DEAR SIR: The following are the results of the analysis of the calcareous sediment, which was formerly examined by me, as I now find, not very accurately:

| | |
|---|---|
| Organic matter | 69.16 |
| Lime | 19.68 |
| Magnesia | 4.66 |
| Phosphoric acid | 1.52 |
| Iron and alumina | 1.00 |
| Carbonic acid | 0.95 |
| Silica | 0.13 |
| Loss, &c | 2.90 |
| | 100.00 |

"The large proportion of carbonate of lime given in my former analysis is a mistake, which arose from the incineration to drive off organic matter. The phosphates served to give, with tests, the reactions indicative of the presence of phosphoric acid, but the excessive proportion of phosphate of lime then obtained was due to

*See note C, page 556, above.

the use of a less perfect method of separation, and also to a less thorough examination than I have at present employed. I was at the time very much occupied with other matters, and obliged to work hastily. These were also the causes of my failure at first to detect the presence of manganese and alumina.

"Yours, truly,

"J. B. REYNOLDS."

"Professor R. S. McCulloh."

To check Mr. Reynolds's examination I gave a portion of the same substance to Professor J. C. Booth, an accomplished chemist, and requested him also to make an analysis of it. The following are his results:

"Philadelphia, *December* 7, 1848.

"My dear friend: The incrustation you handed to me for analysis contains—

| | |
|---|---|
| Organic matter and water | 68.19 |
| Lime | 21.71 |
| Magnesia | 3.65 |
| Phosphate of iron, alumina, &c. | 3.80 |
| Insoluble matter, silex | 0.11 |
| Carbonic acid | 0.60 |
| | 98.06 |

"A very small portion of lime, say 0.6, is combined with carbonic acid. The remainder, together with the magnesia, is united with organic matter, the nature of which was not investigated. The phosphates of iron, alumina, and lime were so small in quantity (the acid forming a small part of the 3.8) that it was not thought worth separating.

"With esteem,

"JAS. C. BOOTH.

"Professor R. S. McCulloh,

"*United States Mint.*"

Hence it follows from these analyses, which differ but slightly, that the calcareous sediment is composed chiefly of organic matter and lime, and that M. Avequin's hypothesis, that lime acts in the defecation of cane juice by forming an insoluble phosphate of lime, is not sustained.

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NOTE H.

*On evaporation in vacuo.*

Several important enterprises which were in progress, or contemplation only, when my report on the manufacture of sugar was written, two years ago, have since been fully and fairly tested.

The apparatus of Dégrand and Derosne has been successfully employed by Messrs. Valcour Aime and Lapice for making pure white sugar, similar to that manufactured with Rillieux's apparatus, directly from the cane juice of Louisiana. And many planters have adopted the practice of evaporating in vacuo, who formerly used open pans, heated either directly by fire or by steam.

Much valuable practical knowledge has thus been acquired and placed within the reach of every planter of that State, in the form which is ever the most desirable, as the authentic results of actual and sufficient working. And those who may now wish to avail themselves of modern improvements will find a careful examination of the different methods in use, made by themselves, upon the spot, far more instructive than anything which could be written elsewhere.

By the entire results of the enterprises in operation, the comparative merits of the rival systems of Derosne and Rillieux must shortly be decided in the most complete and satisfactory manner. But until that decision shall have been definitively pronounced, each of these rival systems will, doubtless, have advocates for its adoption, in those who may be interested in its sale, or who have been induced to extend to it their favor and patronage.

For my own part, though charged by some with disparaging the value of Derosne's apparatus, and unduly extolling that of Rillieux, and by Mr. Rillieux, himself, censured (chiefly by reason of some inaccuracies which occurred through inadvertency in my report,) for having unjustly attributed to Derosne that which he claims to be due to him alone; I have sought, and shall seek only the truth. A stranger to all interest in this matter, I venture to express, without prejudice or partiality, such opinions only as appear to me indicative of the probable result, and worthy of credit, because they are based upon firmly established scientific principles; and I cite as incontrovertible authority only the statements of those who testify, from personal knowledge, and apparently without interested motives, concerning facts already established. Thus I hope at least to avoid leading the planters into error, even if I fail to aid them in searching for complete and certain information.

In De Bow's Review for March, 1848, vol. v., page 252, Mr. Valcour Aime says: "With one of Derosne's or Rillieux's apparatus, the Louisiana planter, instead of getting from three to four cents for his brown sugar, may get for it five or six; for, when I say that I obtain, on an average, eight cents for my white sugar, it must not be understood that I can make by means of the apparatus as many pounds of white sugar as by the usual process could be extracted in brown sugar from the same cane juice; the yield of white sugar is of course smaller, but the increase in price is more than a compensation for the diminution in the quantity. In other words, the same cane juice which, by the usual process, would yield a hundred thousand pounds of brown sugar, which, at four cents, would produce four thousand dollars, will, by means of the apparatus, give white sugar of different grades, for which from five to six thousand dollars may be obtained. This is certainly a hand-

some compensation for the additional trouble and the additional investment. It must, however, be understood as applying only to a well managed apparatus; for we had instances, during the last season, of planters doing worse with the new improvements than with what Mr. McCulloh calls the old and faulty method." Also, in a communication to the Agriculturists and Mechanics' Association, by the same gentleman, which was published in De Bow's Review, vol. iv., page 424, and which accompanied some specimens of sugar sent for exhibition at their annual fair, he says:

"These products have been obtained by means of the apparatus of Derosne and Cail, made by Messrs. Stillman, Allen & Co., of New York, with some modifications of the plan first adopted by the inventor. These modifications consist principally in some changes in the distributors, in the form of the vacuum kettles, and *above all, in the strength of the air pumps*."

"This apparatus was received at the plantation of Mr. Valcour Aime, in 1845, too late to be put into operation for the taking off the preceding crop. *The air pump, as first made, was too weak, and it was found necessary to make another.*"

"The Agricultural and Mechanics' Association has been incorrectly informed by those who induced the society to publish, in the annual report of 1846, that the first cost of the apparatus amounted to $22,000, and that the contract for the modifications to be added would amount to $8,000. The apparatus, as it at present stands, cost $24,000. By it eighteen hogsheads can be made in 24 hours, and the whole of his last crop has been manufactured in this manner."

"Being neither a speculator nor a manufacturer of machines, Mr. Valcour Aime does not persuade any one that the apparatus he has adopted is the best that can be made. His only wish is that, by exhibiting these specimens to the inspection of the sugar planters, they may be enabled to compare them with those made by other processes, and thereby augment the amount of knowledge among the producing classes. These specimens have not been especially prepared for the fair. He has chosen them, as far as possible, with a view to give an idea of his average crop."

"He abstains from furnishing any comparative tables to show the number of thousands of dollars that can be gained on a crop by making use of this apparatus; and he advises the society not to grant the sanction of its name to any tables of this kind, but after the most severe and minute examination. Experience has demonstrated that these tables cannot be depended on, unless they are the results of conscientious and disinterested trials, repeated during several years. He will merely state that he believes he has a knowledge of all the machines which have been erected in Louisiana for several years past, for the purpose of improving the manufacture of sugar, and he thinks the results obtained by the apparatus that he has had erected are at least equal to any other, and that the planters who can afford the expense would be gainers by erecting similar ones. He believes that the economy in fuel, and the increased price of the products, will justify the expense, notwith-

standing its being very great. He is, however, convinced that the disbursements can be covered by the difference in the price of the first or of the second crop."

"Mr. Valcour Aime thinks it his duty to add, that the apparatus of Rillieux, which he constructed on the same principles as that of Derosne and Cail, will, in his opinion, produce the same results. The expense of putting up either is about the same."

"The Agricultural and Mechanics' Association has certainly been led into error, in stating in the report of last year that the negroes employed on a plantation can conduct these machines *without the assistance of a sugar maker*, and that the planters in the northern parishes of the State may, in using them, obtain *fine sugar from the sour juice* of frozen canes. Such an error might occasion great loss to be sustained by many planters. The apparatus of Rillieux, as well as that of Derosne and Cail, is too complicated to be entrusted to negroes without the active superintendence of an experienced sugar maker; and a more thorough examination will convince the society that, when cane juice is really sour, it is impossible to make good sugar either with the one or the other apparatus."

Again, in volume 4, page 383, of the same periodical, Mr. Valcour Aime adds: "I repeat my statement to the agricultural society, that every planter, with sufficient means, who feels that he can give to the apparatus of Derosne or Rillieux the close attention which they require, will find it to his advantage to have one put up. His additional trouble and expenses will be fully compensated by the economy in fuel, in the quality of his sugar, and in the augmentation of the quantity produced, which can, I think, be fairly valued at almost 15 per cent., as far as I can judge from my own experience."

In an unpublished letter of August 17, 1848, addressed to a mutual friend, Mr. Lapice, of St. James, informs me that the Derosne apparatus upon his estate was "not completed last year in the small details, so important to its working with that economy and regularity which is to be expected of it, although *the result was satisfactory*." He speaks in terms of high praise of it, as "possessing *great advantages over all other improvements* for making sugar out of cane juice, as well as for refining," and says that he has "made important modifications, such as disconnecting entirely the concentrating of syrups from the granulating, using Derosne's method for evaporation, (that is, using all the latent heat contained in the steam, which is the only way to economise fuel,) and finishing or granulating in a Howard pan."

Mr. Lapice also did me the honor to promise that, if I could wait until January, he would furnish for this edition of my reports "an account of the taking off of the next crop, such as has never been made exactly; showing the consumption of fuel; the quantity and quality of sugar made with each density of the cane juice; the difference between the new apparatus and the kettles; the quantity of sugar that can be refined after taking off the crop; the difference in economy of manual labor and time required to purge

the sugar and get it ready for market, by working tigers on a large scale, so as to suit our country," &c., &c. He also says, that he "will have the apparatus complete and in full operation this season," and liberally offers the fruits of his knowledge and experience to others.

I regret exceedingly that I have no power to delay the printing and publication of this document for a sufficient length of time to enable me to avail myself of Mr. Lapice's offer. Such a detailed statement as he describes would be of great value to the sugar industry, containing, as it would, many well observed and authenticated facts; and, if Mr. Lapice will yet furnish it, I will either communicate it to the public, with such accompanying remarks as may seem appropriate, through the medium of De Bow's Review, or make of it the subject of a supplementary report.

In an article by J. P. Benjamin, esq., on the sugar industry of Louisiana, written for and published in De Bow's Review, vol. 2, page 322, (which I regret not to have seen when it first appeared, and before the publication of my third report,) after describing both the old and the new method of manufacture, he says:

"Such are the outlines of the system introduced into the manufacture of sugar by Messrs. Degrand, and Derosne and Cail, and before treating of the reasons why the concentration to the granulating point, when effected in the vacuum pan, is a vast improvement over boiling in the open air, it will be convenient in this connexion to point out in what respect the apparatus of Mr. Rillieux differs from that of Derosne and Cail, and to compare the advantages of the two systems. In the Rillieux apparatus the defecators, the filters, and the vacuum pan for granulating the sugar, after the concentration of the syrup to twenty-eight degrees, are all borrowed from the Derosne and Cail apparatus. There may be some difference in mechanical details, but the principle and manner of working are substantially identical. But to Mr. Rillieux is justly due the credit of a very ingenious and admirably efficacious mode of evaporating the juice and supplying the caloric necessary for the granulating pan with very great economy of fuel. In cane juice, at nine degrees of density, there are 83½ per cent. of water, and at 28 degrees there are but 48½ per cent. of water. In order, therefore, to concentrate the juice from 9 to 28 degrees, it is necessary to evaporate from the juice 35 per cent. of the water. Mr. Rillieux conceived the happy idea of making use of the steam that is evaporated from the juice itself in order to boil his pans, and the planter who is accustomed to see the enormous quantity of vapor that is carried off into the air through his steam chimney when he boils in the open kettles, can form some idea of the very great economy of fuel that must necessarily result from making this quantity of steam subservient to his use during the grinding season. Mr. Rillieux's apparatus effects this object. It consists, when made on a scale sufficiently large to make from twenty to twenty-five hogsheads of sugar per day, of four pans, all constructed so as to afford a vacuum. But the vacuum in the two first pans is not nearly as perfect as in the two last. The operation is con-

ducted thus: The cane juice, after having been once filtered, is introduced into the first pan, and this pan is boiled by the exhaust steam from the cylinder which works the mill, thus avoiding the necessity of abstracting any steam directly from the boilers. This first pan is so constructed that the steam which arises from the juice as it boils is conducted into the pipes that heat the second and fourth pans. In the first pan the quantity of steam that arises is quite sufficient for this purpose; but if, at any time, it be found that the fourth pan, in which the sugar is granulated, is not supplied with a sufficiency of steam from the first, a communication can be opened to the exhaust steam from the engine, which supplies any deficiency, and enables the sugar maker to bring his battery to the striking point as rapidly as he may desire. The juice is brought up to fifteen or sixteen degrees in the first two pans, and the steam from the second pan is made to boil the third, in which the syrup is concentrated, to twenty-eight degrees, when it is passed through the filters, and then conducted to the last pan, in which it is granulated.

"I consider the Rillieux plan of evaporation decidedly superior to that of Messrs. Derosne and Cail in several important particulars: 1st. The juice is evaporated in a close pan, and is excluded from atmospheric action; whereas, in the Derosne and Cail apparatus it is exposed to the open air in a state of minute subdivision as it falls in a cascade over the frame of pipes which form the condenser. 2d. It is much less liable to derangement than the frame of pipes, which frequently gives great trouble, and which, unless in perfect order, injures the juice by deepening its color whenever it remains on any part of the heated pipe long enough to be burnt. 3d. It economises the steam which is created by evaporating the cane juice, and which, in the Derosne and Cail apparatus, passes off into the open air through a steam chimney. Against all these advantages the Derosne and Cail offers but one which may be of value in the West Indies, on certain estates, but which is of no moment in Louisiana, that is, an economy of cold water.

"I give here the conclusion to which I have arrived, after as careful and impartial an examination of the two systems as I am capable of; but if I am mistaken, the experience of the present winter will afford ample means of correcting the error. The apparatus of Mr. Rillieux has been erected in its largest size, and in connexion with a refinery, on the plantation of Mr. J. B. Armant, of St. James parish; and Mr. P. M. Lapice, of the same parish, has erected a magnificent sugar house and refinery on the largest scale, with the apparatus of Derosne and Cail in its most approved form. I have every confidence that both these enterprising gentlemen will reap a rich return for their heavy investments in these improvements, and their experience will decide the question of superiority in point of efficacy and economy between the two systems. The only question will be one of degree, for that both will succeed is beyond a doubt.

"The sole remaining subject which it is my intention to examine, is the difference between the system of boiling in the open

air and in the vacuum pan, as regards the quantity and quality of the sugar produced. To place this matter in its clearest light, it is necessary to state certain conclusions which are the result of the researches and experiments of eminent chemists, who have devoted their time and labor to this subject. I have already mentioned that there is naturally no molasses in the sugar cane, and that all the molasses which is produced in our sugar houses is the result of imperfect manufacture. It is not hence to be inferred, however, that it would be possible to manufacture the sugar entirely without a residue of syrup or molasses. A syrup at 45° density contains 83 per cent. of sugar, and 17 per cent. of water, but if this syrup be allowed to cool, in order to crystalize, it will part with only 50 per cent. of sugar in crystals, and the remaining 33 per cent. of sugar will be mixed with the 17 per cent. of water; the two together forming what is called the mother liquor, or mother of crystals. If this mother liquor, which now contains one third of water be again boiled, so as to concentrate it to 45°, and again allowed to cool, the proportion of crystals will again be the same, and there will remain a mother liquor which it will be necessary to reboil, so that the process might be continued indefinitely, and there would still remain a sweet liquid containing a part of the sugar. However perfect the system of manufacture, therefore, a residue of molasses or syrup will always be obtained, and the great aim in this manufacture must therefore be, to reduce this residue as far as possible, or in other words to extract from the juice as much crystalized sugar as possible, that being the most valuable product. Now it has been found that a *high temperature* and *long exposure to heat* are the two greatest obstacles to the crystalization of sugar; that in proportion as the temperature is increased the quantity of crystals will diminish, and further, that in proportion to the length of time that heat is applied, will the crystalizing power diminish. Repeated experiments have placed these two principles beyond question. Those who are curious on this subject, will find a very interesting paper in the seventh volume of the journal of the Franklin Institute, translated from Hochstetter, an eminent German chemist, and containing a series of experiments made on sugar with great care. It results from these experiments: 1st, that access of atmospheric air is not only a condition necessary to produce vinous fermentation, but also to effect the mucous fermentation in the expressed juice of the sugar cane, and that when the air is excluded no change takes place; 2d, that a pure solution of sugar is changed through the influence of atmospheric air at a common temperature, and the more readily the more numerous the surfaces are which bring them into contact, and that this process is considerably heightened when the solution of sugar contains nitrogenous substances, as in the juice of the sugar cane. This is an important objection to the condenser of the Derosne and Cail apparatus; 3d, that heat is one of the most injurious agents during the process of manufacture.

"A simple application of these principles will show the vast superiority in the manufacture by the vacuum pan. In the open ket-

tles the syrup is brought up to a temperature of 235° at least, before it is at the proper point for crystallizing. In the vacuum pan the temperature is only 150°. In the open kettles the juice, from its first leaving the mill till it is concentrated in the battery, is constantly exposed to the action of the atmosphere. In the Rillieux apparatus it is almost constantly excluded from this influence. Finally, when the sugar is made in the vacuum pan the simple turning of the steam-cock shuts off the heat at the instant the granulating point is obtained, and the whole contents of the pan are then discharged in a homogenous state. In the open battery it is not possible to stop the fire when the proper point is attained, and, during the whole time that the sugar boiler is occupied in discharging the battery, the syrup is becoming more and more heated, that which is on the edges of the surface next to the metal becomes burnt or caramelized, and is not only lost, but imparts a deeper color to the rest of the syrup, and also aids largely in forming molasses, by preventing crystallization in that part of the syrup with which it becomes mixed."

"The effect of the high temperature required in the open battery is such that it is almost impossible to reboil the molasses which drains from the sugar, so as to obtain a second crystallized product in the manner above explained. As this molasses, when again put into the battery, would require to be a second time exposed to a temperature of 235° or 240°, the action of this extreme heat is such as to render the whole mass totally uncrystallizable; but in the vacuum pan the reboiling of the syrups which drain from the first sugars is a regular part of the daily work; and this reboiling has been effected three times, with successful results of crystallized sugar each time. But the advantages of the vacuum pan do not end here; for it is an easy and simple matter, in using these pans, to give to the crystal or grain of the sugar any size required by the caprice of the consumer. Large and brilliant crystals, resembling sugar candy rather than the sugar of commerce, can be obtained at will. The whole process is under the complete control of the manufacturer. The sugar may be made light and porous, or compact and heavy. None of this control is possible with an open fire, of which it is impracticable to regulate the heat at will."

"It may not be uninteresting, in conclusion, to make some calculation of the pecuniary results from the introduction of this improved apparatus. I speak now of that of Mr. Rillieux, not being able to give as yet any results from the Derosne and Cail apparatus, which has not hitherto been fully tested in this State. Suppose a plantation to produce an average crop of five hundred hogsheads of sugar, a moderate estimate of the profits of the apparatus would comprise—

| | |
|---|---|
| 1st. An economy of one and a half cords of wood for each hogshead, 750 cords, at $2 50..... | $1,875 00 |
| 2d. An increased value of at least one and a half cent per pound, in the quality of sugar produced, equal to $15 per hhd..... | 7,500 00 |

| | | |
|---|---|---|
| 3d. At least 25 per cent. additional sugar obtained from the molasses, say 125 hhds., at $60..... | $7,500 00 | |
| From which must be deducted the price that would have been obtained for the molasses, 15,625 gallons, at 15 cents..... | 2,343 75 | |
| | | 5,156 25 |
| | | 14,531 25 |

"Making the enormous difference of $14,531 25 in the annual revenue of the planter who makes an average crop of five hundred hogsheads. I am aware that this result is so startling as to provoke incredulity, yet I have purposely placed the lowest estimate possible in each item of the calculation. That there are some drawbacks is not to be denied. I consider it not to be at all practicable, or, if so, highly imprudent to rely on slaves to work the apparatus. I think that the planter who determines to adopt the improvements should make up his mind to have in his employ at least two white persons to take charge of the apparatus during the grinding season, so as to have at least one white person at the pans on each watch. Sugar boilers accustomed to the labor and understanding the working of the vacuum pans can be obtained without difficulty for from five to seven hundred dollars each during the grinding season, and will soon be obtained at a lower rate, as the demand for services will increase their number, and competition will reduce the price, for the labor is not severe and lasts but seventy or eighty days. The negroes too, who are employed in the sugar house, require some instructions in the different processes of defecation, filtration, revivification of the bone black, &c., but all these matters are of trifling moment compared with the great results to be attained.

"In concluding, may I not be allowed to congratulate your readers on the prospects of permanent prosperity in this the most important branch in our State industry, and largest resource of State wealth. A fortunate concurrence of circumstances rendered harmless the reduction in the protective duty which had been levied in favor of this very extensive manufacture. The sudden and unexpected repeal by Great Britain of that provision in her laws, which discriminated between sugar grown by slave labor and by free labor, has destroyed the barrier of prohibition which prevented the import into that country of the Cuba sugars; and the still farther prospective reduction in the English duties secures us against a competition which must have ruined two-thirds of our planters. The largely increased consumption, which must inevitably result in Great Britain from the reduction of prices consequent on the diminution of the duty, will suffice to absorb so great a portion of the Cuba crop as to leave to our State almost the exclusive supply of the home market. The extent to which the production of sugar can be carried in Louisiana is appreciated but by few; but those who reflect on the subject and who feel an interest in all that concerns the prosperity of our State, foresee with exultation the day not far distant when boundless tracts now covered by the primeval forest,

shall teem with plenteous harvests of the cane; when nearly every plantation shall be a manufactory of refined sugar, supplying not only the wants of our own country, but forming a large item in our annual exports; when, in a word, the industry and enterprize of our population shall succeed in developing to their full extent the resources which a bounteous Providence has lavished on this favored land."

Finally, in De Bow's Review, vol. 4, page 425, Mr. Lesseps gives the following experimental results:

"Having a desire to ascertain the difference that might exist in the manner of making sugar by the ordinary kettles, and the apparatus of Rillieux, I caused to be cut down 25 arpents of cane, on the 12th of November last, which I made into sugar, and which yielded 26 hogsheads, and about 73 gallons of molasses per hogshead."

"Five days later I had 25 arpents more cut down in the same part of the field, which, by the apparatus of Rillieux, yielded 32 hogsheads of sugar, and 53 gallons of molasses. The average weight of the two qualties was from 1,050 lbs., to 1,075 net."

"In order that the one mode of making sugar should have no advantage over the other, I caused these 50 arpents of cane to be cut in the following manner:

"My field presents a front of 10 arpents by 5 feet in depth. I took numbers 1, 3, 5, 7 and 9 for the kettles, and numbers 2, 4, 6, 8 and 10 for the apparatus of Mr. Rillieux."

"On my plantation at Poverty Point, I had 66 hogsheads of sugar on the cistern; with the molasses which drained from the same, I obtained about 22 hogsheads of sugar by a second operation."

The preceding statements serve to prove: 1st, that decided advantages attend the use, both of the systems of Derosne and Rillieux, in place of the open pans which are generally employed. 2d, that those planters, who have tried these systems, appear, respectively, to prefer that which they have adopted. To decide their comparative merits in a practical, and entirely satisfactory manner, it is necessary, either that such complete data as those spoken of by Mr. Lapice, in the letter above referred to, should be furnished for each system; or that some enterprising planter should subject the two systems to a perfectly similar, thorough and impartial trial. Such information is, at present, very desirable; and in the absence of it, those planters who have hitherto used open pans, and who wish to adopt the most improved method and apparatus, must be guided very much by interested statements, which are, of course, to be received with great caution, and by opinions, which, however probable, are yet liable, more or less, to error and uncertainty.

In my report on the manufacture of sugar, in 1847, I not only classified and described the various kinds of apparatus used for evaporating saccharine solutions, (which descriptions were designed, not for machinists, but for planters and refiners, and were, therefore, prepared without that degree of care which would have prevented some slight inaccuracies of detail which occurred both in the diagrams and in the text,) but I also stated the practical re-

sults which had attended their use, and frankly expressed my opinions in each instance, where any uncertainty seemed to exist—assigning for such results, and such opinions, reasons founded only on physical laws Errors of fact have been pointed out, which I have endeavored to correct in this revised edition; but my opinions, some of which have been freely criticised, remain, after full and candid consideration of those criticisms, and increased information on my part, generally confirmed rather than altered or dispelled. To the planters it belongs to judge to what extent they may be erroneous, or worthy of any confidence.

In article 30, page 86, of my report, I made the following remark:

"To planters who are obliged to depend greatly upon the begassa of the crop for their supply of fuel, Rillieux's system presents great advantages over all others; for the economy of fuel is so great in it, that the begassa alone is amply sufficient for the crop, even in Louisiana, where the immature nature of the cane and the humidity of the climate are far less favorable for drying begassa, and where, therefore, this article is much inferior to that used in the West Indies. But *if fuel be abundant*, an open steam evaporating pan for concentration to 27 deg. Beaumé, and a simple vacuum pan, either that of Howard or that of Rillieux, will give equally satisfactory results; the juice being in each case similarly defecated and filtered through bone black."

This statement was criticised by Mr. Rillieux, in De Bow's Review, vol. 5, page 292, as follows:

"Since Mr. McCulloh was in Louisiana many apparatus have been used, and among them the kind above referred to by Messrs. Gordon, Johnson, & Osgood, and the result is far from being as satisfactory as by the 'N. Rillieux's Apparatus.' The sugar is inferior in quality, and the consumption of fuel is from 15 to 25 per cent. greater than by the common set of kettles. It is true, however, that such apparatus, or a double vacuum pan apparatus, if properly built, will give as good and as much sugar as Rillieux's, and consume no more wood than a good set of kettles. But neither Professor McCulloh, nor any other writer on sugar apparatus, has yet pointed out the indispensable requisite to obtain such a result; and the apparatus built in this or any other country are a positive proof that the builders are not aware of this requisite. Now I will endeavor to come to a true estimate of the relative value of these apparatus of the same boiling power, giving the same quantity and quality of sugar. One an open steam evaporating pan and strike vacuum pan—one double vacuum pan apparatus—and a N. Rillieux's three pan apparatus. Thus:

*Lowest estimated cost of first and second* 8,000 *pounds boiling power apparatus, as compared with a* 3 *pan N. Rillieux apparatus of the same boiling power.*

| 8,000 pounds boiling power. | Sufficient to take off a crop of 440,000 pounds first sugar. | | | | | |
|---|---|---|---|---|---|---|
| | Apparatus 1.—Open steam pan and strike vacuum pan. | | Apparatus 2.—Double vacuum pan. | | Apparatus 3.—3 pan N. Rillieux. | |
| Consumption of wood per each 1,000 pounds of first sugar.. | 3½ cords. | | 3½ cords. | | 1½ cord. | |
| Consumption for the whole crop..... | 1,540 cords. | | 1,540 cords. | | 550 cords. | |
| Saving of wood by N. Rillieux..... | ..... | | ..... | | 990 cords wood. at $2 25..$2,227 50 | |
| Clarifiers..... | | $800 | | $800 | 3 | $900 |
| Filters..... | 6 | 600 | 6 | 600 | 6 | 750 |
| Vats for filtered cane juice and syrup..... | 2 wood | 100 | 2 wood | 100 | 2 iron wt. | 250 |
| Boiling apparatus { Open steam pan..... | 1 | 800 | | | | |
| Boiling apparatus { Vacuum pan..... | 1 | 1,500 | 2 | 3,000 | 3 | 5,100 |
| Air pump and connexion to the mill engine..... | 1 | 300 | 1 | 500 | | |
| Pumping engine ..... | | ..... | | ..... | | 1,800 |
| 100 feet, 32 in. boilers; wanted besides the mill engine boilers, with pipes, valves, &c ..... | | 1,500 | | 1,500 | | |
| Cast iron and copper connecting pipes for app. cocks, valves, &c | | 600 | | 800 | | 800 |
| Cost of setting up..... | | 300 | | 300 | | 400 |
| Total..... | | —— $6,400 | | —— $7,500 | | ——$10,000 00 |
| Brick work for setting 4 40 feet × 32 inch boilers, furnace, and chimney, 80,000 bricks..... | | 800 | | 800 | | |
| Lime and laying ..... | | 200 | | 200 | | |
| Fixing mill engine furnace and foundation for pumping engine | | ..... | | ..... | | 300 |
| Carpenter's work..... | | 500 | | 500 | | 500 |
| Total..... | | —— 1,500 | | —— 1,500 | | —— 800 00 |
| Whole cost..... | | 7,900 | | 9,000 | | 10,800 00 |
| Fuel saved first crop..... | | ..... | | ..... | | 2,227 50 |
| Actual cost of the apparatus after the first crop..... | | 7,900 | | 9,000 | | 8,572 50 |

"The above table shows the prices of the three different apparatus, each of 8,000 lbs. boiling power, set up, including brick work and carpenter's work, to be $7,900, $9,000, and $10,800. Now, the saving of fuel by the last apparatus on the first crop of 440,000 lbs. of first sugar is $2,227 50, and if this saving be credited to the price of that apparatus, then they stand thus—$7,900, $9,000, and $8,572 50; and the three pan N. Rillieux apparatus costs less by $427 50 than the double vacuum pan apparatus, and $657 50 more than the open steam pan and vacuum pan apparatus after the first crop. And if 20 per cent. be a fair return for outlay in apparatus, then the three pan N. Rillieux apparatus, which saves annually $2,227 50 in fuel, is worth $11,137 50 more than the two other apparatus. The price of a "N. Rillieux" three pan 8,000 lbs. boiling power apparatus, set up complete, including the brick and carpenter's work, being $10,800, the others are worth, set up, brick and carpenter's work included, $337 50 *less than nothing;* and if the planter has to pay for the brick and carpenter's work as usual, then the builders of those two apparatus ought to give them, set up complete, and $1,837 50 besides, to the planter, to put him in the same economical situation as if he had purchased the N. Rillieux apparatus."

To these remarks of Mr. Rillieux I may reply that, in the very paragraph which he quotes I admit and assert the superiority of his apparatus with reference to this economy in fuel, for which he contends, and which I also endeavored to prove by calculations in article 33; and that he seems to assent to my statement, if the apparatus be "properly built"—a condition implied.

In the same number of De Bow's Review, vol. 5, page 285, there was published a letter from Mr. Rillieux to Mr. W. E. Thompson, dated January 29, 1848, which the latter gentleman also caused to be printed and issued in the form of a circular. In that letter Mr. Rillieux says:

"There are in now in Louisiana eight different methods used in making sugar, viz:

1st. The old set of kettles;
2d. Set of kettles for syrup, strike high pressure steam pan;
3d. Set of kettles for syrup, and strike vacuum pan;
4th. Open high pressure steam pans for syrup and strike;
5th. Open high pressure steam pans for syrup and strike vacuum pans;
6th. One syrup and one strike vacuum pan, clarifiers and filters;
7th. 'Degrand's' apparatus, clarifiers and filters;
8th. N. Rillieux's three and four pan apparatus, clarifiers and filters."

For the comparative results of these methods he gives the following tables, the first of which I have modified, but in its arrangement only:

## FIRST TABLE.

*Showing the value of a crop of cane, made into sugar by six different methods, into hogsheads without being syrupeu, at the price each kind has been sold at, or is worth this season.*

The whole quantity of dry sugar being in each case 653,367 pounds, and the boiling power required to take off each crop being 8,000 pounds.

| Method. | Pounds of first sugar. | Value per lbs. in cents. | Total value of first sugar in dollars. | Pounds of second sugar. | Value per lb. in cents. | Total value of second sugar in dollars. | Gallons of molasses. | Value per gal. in cents. | Total value of molasses in dollars. | Total value of the crop. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 433,000 | 4½ | 19,485 00 | *43,300 | 2 | 866 00 | 26,734 | 18 | 4,812 12 | 25,163 12 |
| 2 | 433,000 | 4½ | 19,485 00 | 153,500 | 2⅝ | 4,221 25 | 13,857 | 18 | 2,494 12 | 26,200 37 |
| 3 | 433,000 | 5 | 21,650 00 | 162,000 | 3¼ | 5,265 00 | 12,874 | 18 | 2,317 32 | 29,232 32 |
| 4 | 433,000 | 4 | 17,320 00 | 153,500 | 2½ | 3,837 50 | 12,857 | 18 | 2,494 12 | 23,651 62 |
| 5 | 433,000 | 5½ | 23,815 00 | 162,000 | 3½ | 5,670 00 | 12,871 | 20 | 2,574 80 | 32,059 80 |
| 8 | 440,000 | 6¼ | 27,500 00 | 163,000 | 4¾ | 7,742 50 | 11,949 | 20 | 2,389 80 | 37,632 30 |
| †8 | 478,500 | 6 | 28,710 00 | 141,000 | 4½ | 6,345 00 | 10,041 | 20 | 2,008 20 | 37,063 20 |

Comparative expenses, consumption of fuel, profits, &c., &c.

| Method. | Plantation expenses. | Bone black expenses. | Wood consumed, cords. | Saving or loss in full, in dollars. | Net proceeds. | Relative gain by method 8. | Cost of apparatus. |
|---|---|---|---|---|---|---|---|
| 1 | 7,000 | ..... | 1,515 | ..... | 18,163 12 | 13,440 43 | $2,000 |
| 2 | 7,000 | ..... | 1,515 | ..... | 19,200 37 | 12,403 18 | 2,500 |
| 3 | 7,000 | ..... | 1,515 | ..... | 22,232 32 | 9,371 23 | 4,000 |
| 4 | 8,000 | 200 00 | 1,948 | L. 974 25 | 14,477 37 | 17,126 18 | 12,000 |
| 5 | 8,000 | 200 00 | 1,948 | L. 974 25 | 22,885 55 | 8,718 00 | 12,000 |
| 8 | 8,000 | 200 00 | 550 | S. 2,171 25 | 31,603 55 | ..... | 10,000 |
| †8 | 8,000 | 200 00 | 550 | S. 2,171 25 | 31,034 45 | 569 10 | 10,000 |

* Cistern's bottom. † High boiling.

## SECOND TABLE.

*Showing the value of a crop of cane, made into sugar by methods 6, 7, and 8, in hogsheads. Sugar without being syruped, at the prices each have been sold at this season.*

| 15,000 to 16,000 pounds, boiling power apparatus. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | METHOD SIXTH. | | METHOD SEVENTH. | | METHOD EIGHTH. | | | |
| | *Double vacuum pans.* | | *Degrand's apparatus.* | | *3 pans—Rillieux's apparatus.* | | *4 pans—Rillieux's apparatus.* | |
| Price of apparatus.... | $18,000. | | $24,000. | | $18,000. | | $20,500. | |
| Wood consumed..... | 2,600 cords. | | 1,400 cords. | | 1,000 cords. | | 540 cords. | |
| First sugar..... | 800,000 lbs. at 6 | $48,000 00 | 800,000 lbs. at 6 | $48,000 00 | 800,000 lbs. at 6½ | $52,000 00 | 800,000 lbs. at 6½ | $52,000 00 |
| Second sugar..... | 285,000 " 4 | 11,400 00 | 285,000 " 4 | 11,400 00 | 285,000 " 4⅝ | 13,237 75 | 285,000 " 4⅝ | 13,237 75 |
| Molasses..... | 15,500 gals. 20 | 3,100 00 | 15,500 gals. 20 | 3,100 00 | 15,500 gals. 20 | 3,100 00 | 15,500 gals. 20 | 3,100 00 |
| Total..... | | 62,500 00 | | 62,500 00 | | 68,337 75 | | 68,337 75 |
| Plantation expenses, including $400 for bone black..... | | 10,400 00 | | 10,400 00 | | 10,400 00 | | 10,400 00 |
| Balance..... | | 52,100 00 | | 52,100 00 | | 58,237 75 | | 58,237 75 |
| Saving of wood..... | ..... | ..... | 1,200 cords at $2¼ | 2,700 00 | 1,600 cords at $2¼ | 3,600 00 | 2,060 cords at $2¼ | 4,635 00 |
| Net proceeds..... | | 52,100 00 | | 54,800 00 | | 61,837 75 | | 62,872 75 |
| Profit over method 6th | ..... | ..... | | 2,700 00 | | 9,737 75 | | 10,772 75 |

In the remarks accompanying these tables, Mr. Rillieux estimates the consumption of fuel, for every 1,000 pounds of sugar, at 3 to 4 cords of wood in methods 1, 2, and 3; at 4 to 5 cords, in methods 4 and 5; at 3 to 3½ cords, in method 6; at 1½ to 1¾ cords, in method 7; and in method 8, at 0.9 to 1.5 cords, for the three-pan apparatus, and from ½ to ¾ of a cord for his four-pan apparatus.

He claims for the sugar made with his apparatus a superiority in quality, though not in quantity, over that manufactured by methods 6 and 7; and he asserts that syruped tiger sugar made with his apparatus by Messrs. Benjamin and Packwood sold for 8 cents, while Mr. Lapice's syruped tiger sugar, made by method 7, sold in hhds. marked Nos. 1, 2, and 3, at 7, 6, and 5 cents. Mr. Rillieux states that hhd. sugar made by method 6, sold at 6 cents, while sugar of the same kind made with his three-pan apparatus brought 6½ cents. Of Degrand's apparatus he, however, says: "The 7th method ought, I think, to give as much and as good sugar as the following, but has not yet done so;" the correctness of which assertion was subsequently denied by Mr. Valcour Aime, who professed to have made, by that method, "from cane juice, sugar of a higher grade, and which is sold at better prices than any which has hitherto been obtained by the Rillieux apparatus."

From the data of the first of the above tables, Mr. Rillieux concludes that the profit on one crop by method 8 over each of the other methods of that table "exceeds the entire cost of an N. Rillieux apparatus," and that the worst method is the fourth. From the results of the second table, he contends "that at the price Messrs. Merrick and Towne sell 'the Rillieux apparatus,' preference should be given to the double vacuum pan apparatus, only if they can be had already set up for nothing, and Degrand's apparatus is only worth half the price of Rillieux's four-pan, and three-fourths the price of Rillieux's three-pan apparatus of the same boiling power."

Mr. Rillieux also says that "the first and second methods are in general use in Louisiana, and give very nearly the same sugar, and exactly the same quantity. Nearly the whole profit from a steam battery arises from the boiling of the molasses. The different strike high pressure pans give the same result, but the worms are the best as they cost less, and are easier kept in repair. Sugar made altogether in open high pressure steam pans is worth less by ¼ to ½ cent per pound than if made by the set of kettles, and the consumption of fuel is 15 to 25 per cent. greater. Sugar made in a set of kettles and finished in a vacuum pan of any description, when well made, is worth ½ to ¾ cent per pound more than when made by kettles alone. The profit arising from a strike vacuum pan pays back twice the outlay in one crop."

The printed circular from which these tables and statements of Mr. Rillieux are extracted led to a newspaper controversy, in which their correctness was disputed. The merits of that controversy I shall not presume to determine. In August last Mr. Rillieux handed me a copy thereof, together with the circular, a pamphlet by M. Dégrand, "*Sur l'evaporation des liquides sucrés*," and

a letter addressed to me by himself; the object of which is stated to be to call attention to some inaccuracies in my report, "so that they may be corrected in the forthcoming reprint."

In Mr. Rillieux's letter to me, he says: "It is difficult to get precise data, because the planters are averse to making their operations known. I was, therefore, in some cases compelled to get my information from persons employed on the plantations. The general correctness of the statements may be inferred from the fact that only two of the planters have made any objection thereto. One objected to the statements in the report, and I refer you to a newspaper correspondence, from which you may judge of the merits of the case. The other briefly denied, in general terms, the correctness of the statement respecting his crop." Mr. Rillieux then proceeds in his letter to maintain the contrary. I do not know whether or not Mr. Rillieux desired me to make any use of his communication, except for the correction of inaccuracies in my report. As it is in part controversial, I do not feel at liberty to embody it in a congressional document; but I have no wish to withhold information from the public, and I shall, therefore, send a copy of it to the editor of De Bow's Review, to be published ornot, as he may prefer. In this document, I will give only such extracts as, in my opinion, can be made with perfect propriety, and as may seem necessary, in order to do justice to every one, and at the same time to throw light upon the general subject of the sugar industry.

Mr. Rillieux also says: "I come now to my apparatus for making sugar; the invention of which I am prepared to trace back to January or February, 1832, by the testimony of gentlemen of the highest standing in Louisiana. In 1834, a part of my invention was described to Derosne and other persons in France; and subsequently, my idea of boiling one vacuum pan by the vapor *from* another, was conveyed to him by persons who can be traced. In 1843, Derosne made a trial of the last idea, in such a defective manner as to show plainly that he did not comprehend it. Mr. Dumas, in the sixth volume of his chemistry, gives a drawing of that apparatus tried by Derosne, which you have copied in your report, and stated to be the same you saw in operation in Cuba, on the estate of Don Villa Urutia, and on the Amistad estate near Guines, owned by the widow Ayesteran and her sons. I have recently seen all the apparatus set up by Derosne in the island of Cuba, except that of Don Contero, and none of them use the steam of one pan to boil another. I afterwards saw Don Contero in Havana, and he informed me it was not so used in his apparatus. Don Ayesteran told me that when you visited their plantation he had only *one* vacuum pan with a Degrand condenser." The inaccuracy in my report, which is pointed out in the passage just quoted, has been corrected in this revised edition; but the more fully to do him justice, I give Mr. Rillieux's statement, and cheerfully acknowledge that it is true in as far as it relates to myself, as well as that I erred through inadvertency.

Finally, he adds: "I hand you herewith a publication by De-

grand, in which he asserts and proves that Derosne, so far from improving the apparatus invented by him, has actually injured it by his modifications.

"Derosne also attempted to deprive Degrand of the credit of his invention; but the royal court of Paris recognized his rights, declared him to be the only and true inventor, and ordered Derosne, under a heavy penalty, to take off his own name as inventor from all the apparatus he had made, and substitute 'Degrand, inventor,' in large letters. In justice to the inventor, I suggest that you record this fact in your report." In publishing this extract from Mr. Rillieux's letter to me, I neither assert nor question its accuracy, of which I know nothing; to Mr. Derosne, who has been dead these two years, it no longer matters what claims to invention may be made by others. I would, however, tread lightly on the ashes of the dead, as well as respect the living; and I shall, therefore, make use of only such portions of Mr. Degrand's pamphlet (which appears to be a hostile attack upon MM. Derosne and Cail) as are not controversial. I will, however, send to De Bow's Review a translation of the entire pamphlet, that its contents may be known to the planters, and criticised by any one who may see fit.

The following statement of Mr. Degrand is at least interesting, if not valuable: "The present state of the manufacture of sugar in France, so far as the evaporation of saccharine liquids is concerned, is as follows: the arrangements, acting continuously upon thin layers of syrup, heated by high pressure steam, and exposed freely to the air, have been abandoned; because, among the numerous varieties which have been tried, none have fulfilled the condition of good working. There are some manufacturers who evaporate entirely in bascule pans, exposed to the direct action of the fire and to the air; occupying two hours and a quarter to bring the juice of the sugar beet to 18° or 20° Beaumé, and three-quarters of an hour to bring this syrup to the striking point. Some evaporate the juice in these pans to 18° or 20° Beaumé, and then employ open pans, heated by steam, to reduce the syrup to its proper density; others, who evaporate entirely by steam at 150°, in open pans, take thirty to thirty-five minutes for evaporation to 18° or 20° Beaumé, and fifteen minutes for concentration. All these manufacturers produce sugar of good quality. Others, again, evaporating entirely by the Degrand apparatus, such as MM. Derosne and Cail construct, do not produce a sugar of irreproachable quality, but at least obtain it with economy in fuel. Still, others, by making use of the Howard apparatus, obtain a good sugar; while there are some who, with the same apparatus, produce sugar in a pasty condition. And finally, good results are obtained by evaporating with steam at 150°, in open pans, to 18° or 20° Beaumé, and then employing a vacuum apparatus of either double or single effect, to bring the syrup to the striking point and to work molasses."

"From the whole of these practical results, it seems that, if only the quality of the sugar produced is considered, there is but little reason to prefer one kind of pan to another; but this view of the subject would be incomplete, for it is also necessary to take

into consideration the coloration of the sugar more or less decided, as well as the quantities of sugar respectively produced by a given weight of beet juice, supposing all the circumstances of the manufacture similar, except the pans or the evaporating apparatus. As for the coloration, the sugar coming from pans exposed directly to the fire is a little more colored than that which is obtained by heating with steam at 150°, in open pans; and this last does not attain to the whiteness of sugar evaporated in vacuum apparatus. On the other hand, the quantity of sugar produced is as much greater as the coloration is less decided."

The paragraph just quoted appears somewhat inconsistent, for the *quality* of sugar is certainly affected by its color; those pans which give sugar of superior whiteness may, therefore, be said to produce it of higher quality. And if we consider the term *quality* as technically synonimous with *crystalline grain*, Mr. Dégrand can scarcely be understood to imply that this does not vary with the different kinds of apparatus.

Mr. Dégrand undertakes, in his publication, to institute a detailed comparison between his own vacuum apparatus and that of Howard, taking into account the original cost, expenses of working, and compound interest thereon. But while he sets forth fully all the advantages of his own and the disadvantages of that of Howard, which he overrates, he neglects to present distinctly the corresponding defects of the one and merits of the other. He also draws this comparison, not between Howard's pan and his own, as constructed by MM. Derosne and Cail, and tested by experience, but between that pan and his proposed arrangements, which have been insufficiently tried; and the conclusions which he deduces are, therefore, not only affected by the bias of his mind in favor of his own contrivances, but based upon data which are more or less hypothetical. It should be borne in mind that it is only in economy of fuel, resulting from the use of the latent heat contained in the vapor which escapes from the boiling syrup, that the apparatus of either Mr. Dégrand or Mr. Rillieux possesses any advantage over that of Howard; and that any fair comparison requires that each of these systems should be allowed all the accessory advantages which it can derive from such ingenious means as, for instance, that of using for evaporation the exhaust steam of the engine of the rolling mill, previously employed expansively by means of a cut-off. All such accessory advantages are excluded by M. Dégrand from his notice of Howard's pan, while he gives it two steam engines and separate boilers to perform the pumping operations it requires. With this brief review, I take leave of his pamphlet for the present, reserving more extended criticisms for such remarks as I may see fit to annex to it if published in De Bow's Review.

In conclusion, although I have set forth the principles upon which economical evaporation depends, somewhat briefly perhaps, but as clearly as is requisite for the comprehension of an intelligent mind, yet it may be well to offer some remarks, which may serve either to present them more fully and forcibly, or to eluci-

date their connexion with the practical problem to which every sugar manufacturer needs to apply them.

On page 236 above, I have enumerated certain established physical truths, which are particular cases under the following general laws:

1st. *It is not less impossible to create power than matter.* Chemistry has long since acknowledged that in all the transformations which matter undergoes, by reason of natural or artificial influences, it suffers no change but that of form. Not a particle is either created or destroyed. Similarly, by the discoveries of modern mechanical and physical science it has been established, that we may modify the action, but can in no way increase or diminish the quantity of force. We may expend it slowly or rapidly. And by our arrangements we may employ it either economically and effectually, or wastefully and in the production of useless results. There is power in a pound of coal, by combustion with the oxygen of the air, to develope a certain quantity of heat; that heat, if applied *entirely* to the conversion of water of given temperature into vapor, is capable of evaporating a certain *invariable* quantity. But if, in the apparatus used for the purpose, more or less is lost by absorption, conduction, radiation, &c., the effective evaporating result will, of course, be proportionally diminished. Hence, furnaces should be so contrived, when practicable, that the amount of heat wasted shall be a minimum quantity; and all attempts to increase their power, in any other way than by preventing loss of heat, are unscientific and visionary.

2d. *Force expended in producing an effect is not destroyed.*—When water is converted into steam, the heat which causes this change is not annihilated; it is communicated to and abides in the steam; and if, by condensation, it be imparted to another and like quantity of water, this in turn will be converted into vapor, which also may yield it to a third portion; from which it can pass to a fourth, and so on, *ad infinitum;* each portion, successively, assuming the state of steam and reverting into that of water, by receiving and then imparting the heat which causes its transformation. Nothing is thus created—nothing destroyed.

In practical operations, however, it is impossible to apply any power without waste; and we cannot, therefore, use the same heat successively without limit and without rapidly decreasing effective results. The causes of loss being those mentioned above—absorption, conduction, radiation, etc.

I have not hesitated to express the opinion of Mr. Rillieux's apparatus, that it possesses superior advantages to that of Derosne, and to all other apparatus for evaporating syrups in vacuo which has been practically tested, and of which I have any knowledge; because he alone of those who have offered their inventions for that purpose to the public, seems to me to have clearly apprehended the idea of using the latent heat of steam *successively*, and to have so constructed his apparatus as to realize this idea practically, thereby attaining that economy in the expenditure of fuel, or heating power, which necessarily results from its continuous employment until

lost by the operation of accidental causes. It is true that Degrand's condenser, or serpentine tube, permits the latent heat of the steam from the vacuum pan to be used a second time; but, so far from attempting to employ the vapor which escapes from the juice concentrated upon the outside of that condenser, he permits it to escape freely into the air, while Rillieux uses the heat of steam again and again.

While, however, I have confidently asserted that the apparatus of Rillieux must be more economical, I have not hesitated to express the firm conviction, that either the vacuum pan of Howard, or that of Derosne and Degrand, possesses equal advantages for the manufacture of sugar of perfect quality. It matters not what may be the form of the pan, or what are the mechanical arrangements by which the vacuum is produced, if that vacuum be sufficiently perfect, and the air pump, whether simple or combined with a condenser, be powerful enough to maintain it when formed, ebullition will take place at a low temperature, and sugar of chemical purity will be made from pure syrup. The size of the vacuum pan, and the rapidity with which the operation is conducted, will exercise an influence upon the grain. But apart from advantages of mechanical construction and economy in fuel, I must confess, I can see no cause for preference of either one of these arrangements for evaporating in vacuo to the others.

Although I accord to the apparatus of Rillieux superiority over others now in use, I do not consider it incapable of improvement, however admirable in its present construction; and it would not be difficult, I think, to point out modifications which would tend materially to increase its effective result; but it is not my purpose, in this essay, to criticise particular arrangements, but rather to give an exposition of general physical truths by which planters and others may be guided.

There is no principle from which greater economical advantages may, in my opinion, be derived by the sugar industry, than that of the successive use of latent heat. I have stated (see page 261 above) that this principle "is neither one lately discovered nor but recently applied; and that it has long formed a part of established physical science." To Mr. Rillieux and to Mr. Degrand may be due the credit of having first combined it with that of evaporation in vacuo, for the manufacture of sugar; but I do not think that either of these gentlemen can claim to have first invented an apparatus for using latent heat successively for the evaporation of syrups, &c. And I can see no chemical reason why cane juice may not be concentrated, say to 28° B., in pans using the latent heat of steam successively and under ordinary pressure. Syrup thus concentrated might be granulated in Howard's pan; and would, I am confident, give sugar of excellent quality. By a calculation, (see page 263 above,) I have shown that a series of four pans is capable of increasing the evaporating effect, produced under atmospheric pressure by a given quantity of high steam, in the ratio of 173 to 100, or nearly as 7 to 4; this is not a mere theoretical deduction, but a result which has been realized upon

a large scale with such an apparatus constructed by Mr. Deroane, which was not known to me when I made the above calculation, and of which a description will be found in the second volume, page 87, of the second edition of Peclet's *Traite de la Chaleur, dans ses applications*, with this apparatus the economy of fuel is said to have been as 9 to 5, or 180 to 100, being very nearly the calculated value.

The importance of economy in fuel to the cane sugar industry is manifest from the fact, that cane juice of good quality contained 15 to 20 per cent. nearly of sugar, and that 80 to 85 per cent. of water must, therefore, be evaporated, or four parts for every one of sugar obtained; certainly, therefore, in operating upon large quantities it is highly desirable to be able, by improved arrangements, to augment the action of the fuel employed in a two-fold or greater degree.

Whenever the latent heat of steam generated in one pan is used to evaporate a liquid in another, it is necessary that the temperature of ebullition should be lower in the second than in the first, in order to cause condensation with sufficient rapidity to let the steam flow readily between them. This may be accomplished, if the use of high steam would produce no injurious chemical effects, by performing the successive evaporations under different pressures, which may be regulated at will by means of valves loaded with corresponding weights. Slight additions of temperature cause very considerable and rapidly augmenting increments of the elastic force of vapors, the latter varying in geometrical when the former are in arithmetical progression. It is not, therefore, practicable, without employing steam of much higher tension than would be proper or safe, to use its latent heat successively in a large number of pans; for if we suppose the steam to be of three atmospheres, or 275° Fahrenheit, and allow a difference of temperature of 25° between each two consecutive pans, which is not more than sufficient, it would be requisite that the fourth pan should boil at the temperature of 200°. This could only take place by aid of a partial vacuum in that pan. Hence it is evident that the limits within which steam may be applied effectually, and without the assistance of a vacuum, are very narrow; and this is particularly the case with reference to concentrated syrups, which are easily injured by subjection to temperatures much exceeding 212° Fahrenheit, especially if long continued. As ebullition in vacuo may take place *at any temperature* above that at which the liquid becomes solid by congelation, it is evident that, by means of an air pump, we may greatly extend the range of temperature, and, consequently, the number of pans in which the latent heat of vapor is successfully employed. If it were possible to construct a pump which would produce a perfect vacuum in the last pan, water would boil in it at 32°, or at its own freezing point; and a series of no less than ten consecutive pans might be used in which the temperatures of ebullition would vary, between the limits of 212° and 32°, by equi-differences of 20°. With steam of 272° (nearly three at-

mospheres) it would be practicable to extend this series to 13 pans.

The assertion that water may be made to boil in vacuo at 32° Fahrenheit, may appear to some strange and even untrue; but such is nevertheless the fact. Boiling or ebullition is, in itself, a mere mechanical agitation, a disturbance of equilibrium which occurs when the vapor, formed in the heated liquid, is of sufficient disruptive or expansive force to overcome both the cohesion of the fluid particles and the atmospheric or other pressure to which it is subjected. It is, therefore, an unimportant phenomenon, and dependent solely upon pressure. By increasing this pressure indefinitely we may prevent ebullition, and water may, therefore, be heated red hot without boiling, if confined in a vessel sufficiently strong; or, on the contrary, it may be made to boil at any low temperature, by diminishing the pressure to the corresponding degree. English authors have generally written incorrectly and obscurely upon this subject. In French treatises it will, however, be found properly and clearly discussed.

Evaporation evidently cannot take place rapidly without ebullition, except by the aid of currents of air, and from an exposed surface; for it is necessary that the vapor should have the expansive force requisite to make its escape freely, especially when close vessels are employed. Vapor forms *at all temperatures*, and as readily from ice as from water. The air opposes to evaporation a resistance which is mechanical only, like that of a vessel in which the liquid may be confined. In vacuo this resistance is removed, and the only requisites to the instantaneous transformation of the whole of the liquid into vapor are the supply of the necessary amount of heat, and sufficient space for expansion. So rapidly do liquids evaporate and absorb heat in vacuo, that water may thus be readily frozen; and an ingenious philosophical toy has been invented by Dr. Wollaston, called by him a *cryophorus*, which serves to show, in an entertaining and instructive manner, the freezing of water by its own evaporation.

Both Mr. Dégrand and Mr. Rillieux assert that high pressure steam cannot be employed for concentrating syrups in vacuo, without injury to their color by overheating. Certainly, if the air-pump be strong enough to produce and maintain a sufficient vacuum, *the mass of syrup* cannot be heated to an injurious degree, even by high steam, in consequence of the powerful refrigerative action of rapid evaporation. But it is possible, and even probable, when bubbles of steam form in contact with the metal of the heating worm or hollow bottom, that they leave thin films of syrup attached to and moistening the hot metal, which may become caramelized before the bubbles escape. This can be ascertained only by observation; and it is a question not of opinion but of fact, to which it is sufficient for me to have directed attention.

In stating that between the limits of 212° and 32°, ten consecutive evaporating pans might be made to boil at equi-different temperatures of 20°, I do not take into consideration the imperfection of a practicable vacuum, &c., which would materially lessen the

number. It would, perhaps, be impossible to form and maintain, with an air pump, a vacuum of less than from two to four inches of pressure; for which the corresponding temperatures, if water be the liquid operated upon, would be 102° to 127° Fahrenheit. To produce rapid condensation, differences of temperature of 20° Fahrenheit, would probably be insufficient. And if we increase these differences nearly to 50°, then with a vacuum of four inches and steam of three atmospheres, that is to say between 125° and 275° Fahrenheit, the series would consist of four pans only, boiling at 125°, 175°, 225°, and 275°, respectively. For manufacturing purposes, this problem must be studied with reference to the maximum working effect; that number of pans and those temperatures being adopted which would give the most desirable result; and all attendant circumstances, such as loss of heat by radiation and in the water formed by condensation, chemical effects of high temperatures, etc., being fully considered.

It should also be borne in mind that in aqueous solutions, owing to the attraction between the water and the substance dissolved, the temperature requisite to give the degree of elastic force necessary to produce ebullition, under any given pressure, must be higher than when pure water is similarly treated; because an additional force, one of chemical union, has to be overcome. A force which depends upon the quantity and nature of the substance dissolved, and which may be either constant or variable with temperature. Thus a saturated solution of

| | | | | |
|---|---|---|---|---|
| Alum | boils | at ..... | 220° | Fahrenheit. |
| Borax | " | " ..... | 222 | " |
| Common salt | " | " ..... | 224 | " |
| Sal ammoniac | | " ..... | 236 | " |
| Nitre | " | " ..... | 238 | " |
| Rochelle salt | " | " ..... | 240 | " |

It is evident that the temperature of steam, after it has once escaped, will depend solely upon the pressure to which it is subjected, and will be the same whether formed from pure water or any solution whatever. Hence, when syrups are evaporated in close vessels, as in vacuum pans, the liquid is hotter than the steam above; and this difference of temperature, under any given pressure, increases with the degree of concentration.

Finally, I may add, that whatever advantages the systems of Derosne and Rillieux may possess, Howard's pan, if heated by steam which has been previously used both for rolling the canes and for working the air pump, and which, when condensed, is returned to the boiler, may be found to be capable of operating with a degree of economy much exceeding the results which have hitherto been obtained with either of those systems. For this purpose, and indeed whenever economy in the use of the steam engine is desired, *the steam must be used expansively*, cutting off at that point of the stroke, and so regulating the velocity as to produce the maximum effect. Also the power of the air pump should be such that a sufficient vacuum can be maintained, say one of four inches, for in-

stance. A worm should be used for heating, instead of a steam-bottom, because it loses no heat, and the external surface of the pan ought to be covered with a nonconducting jacket. To prevent all injury by caramelizing any portion of syrup, the steam used for heating probably should not have a temperature exceeding 220°, or a residual working force of 5 inches after it comes from the engine; experience, however, must determine this point, whether it is better to employ two separate engines or only one for the mill and air pump, is a question concerning which I will only say that one large engine costs much less than two small ones, both in original outlay and current expense, and the waste of heat by two fireplaces and boilers is greater than that of one of double power. It is also less expensive in the end to use steam of not more than five atmospheres, or 60 pounds pressure to the square inch, than steam of 150 pounds, as is often done in our country; the strain being moderate, the wear and tear is less.

If Howard's pan were combined with a double acting pump, which should not only form the vacuum by suction, but also force the vapor disengaged by the syrup into the double bottom or serpentine tube, so as to compress it and elevate its temperature; the idea of using latent heat successively, and for an indefinite number of times, may be realized with a single evaporating pan. The vapor thus condensed in the hollow bottom into water, gives off its latent heat to evaporate a new portion of syrup in the pan, which in turn plays a similar part; so that, if the supply of syrup be kept up, the action will proceed continuously, and the only heat lost will be that of necessity retained by the condensed water, and the portion dissipated by conduction and radiation. As a given weight of steam would, if thus compressed and condensed into water, say at 212°, return to the syrup 1,000° of latent heat, this heat would be capable of evaporating another portion of water which would be to the first in the ratio of 1,000 to 1,212, or nearly as 5 to 6; one-sixth of the heat is therefore lost each time in the water of condensation. Hence, the total quantity of syrup evaporated by the steam from the boiler will be the sum of a decreasing infinite series of which the first term is unity, and the ratio $\frac{5}{6}$ nearly; or therefore as 6 to 1. And if 6 cords of wood be requisite to evaporate a given quantity in a common boiler, one cord should produce the same effect in such a pan. In this estimate no allowance, however, is made for the expenditure of fuel for working the pump, if the power employed for the purpose be that of steam. The ingenious idea of using latent heat successively by compression, and in the manner above mentioned, is due to Mr. Pelletan, who constructed an apparatus for the purpose, an account and description of which will be found at page 93 of the 2d volume of the last edition of Peclet's *Traité de la Chaleur*. The apparatus was not well contrived, and the economical results obtained, though consequently imperfect, were yet three times greater than those given by ordinary steam pans.

NOTE I.

*On pneumatic pans or tigers, by J. P. Benjamin, esq.**

I believe it to be true, that although the *tigers* had been successfully used in liquoring sugar already made, they never had been employed in receiving the liquid sugar as it runs from the battery and converting it into crystals, until the experiment was made on the Bellechasse plantation, belonging to Mr. Packwood and myself; but the success of that experiment is to be attributed alone to my friend and partner Theodore J. Packwood; and I have no hesitation in saying, that any man not possessed to the full degree of his indomitable perseverance, long experience, and intimate knowledge of the behavior of saccharine matter under all the influences of temperature and varieties of manipulation to which it can be subjected, would have abandoned the experiment in despair, as being utterly hopeless. It was only after weeks of severe toil and intense application, that there appeared any prospect of ultimate success; and more than three-fourths of the first crop made with the tigers had been taken off, before they were worked with that steady precision which proved they could be relied on, in the manufacture of sugar, as the ordinary moulds of the refiner.

I have stated that I would treat of the concentration of the syrups and crystallization of the sugar in connection with the working of the tigers, because it is only in that connexion that I can offer you any remarks not to be found in all the treatises on the subject. It was well remarked by your distinguished Vice President, Judge Rost, in his interesting address delivered to the association in 1845, that the vacuum pan has many decided advantages over all other concentrating vessels: that the sugar may be grained in the pan, and that the granulation is completely under the control of the operator, who may accelerate or retard it at pleasure, who may carry it so far that sugar will not run from the pan, and may so conduct it as to increase almost at will the size and hardness of the crystals. All this is true; and it is also true, as he has stated, that the tigers cannot be used for sugar boiled in any other manner than in the vacuum pan. Allow me, then, to explain to you in what manner the tigers are constructed, how the sugars are to be boiled for being worked in them, and the mode of conducting the operations afterwards.

The pneumatic pan or tiger is an oblong box divided into two parts. A convenient size has been found to be eight feet in length and four feet in width. The two parts of the tiger are divided by a frame covered with cloth, made of copper wire, which forms a false bottom; the lower half is of cast iron and is about twelve inches in depth, with a slope from all sides towards the centre, at

*This article is extracted from one, to which I have already referred several times, published in De Bow's Review, vol. v, page 44, January, 1848, and which was prepared as an address to be delivered before the Agriculturists' Association of Louisiana.

R. S. McC.

which point is a cock for draining off molasses from the sugar which is poured into the upper part and which is drained through the seive like false bottom above alluded to. The upper part is about sixteen inches in depth; it is made of sheet iron or wood, with a ledge of about half an inch in width, running all round the inside at the line or junction with the lower half; this ledge serves as the support for the frame, which is also supported from beneath by a thin plank set on edge, and running from end to end of the tiger; the lower part of this plank is scooped out in two or three places, so as to leave free passage for the drainage from all parts of the bottom to the cock at the centre. An opening in the false bottom is connected by a valve with a pipe running to the air pump that is worked by the engine that drives the mill, and another small opening connects with a steam pipe, furnished with a cock by which the steam can be admitted, or shut off, at pleasure, and the use of which will be presently noticed.

The theory of the working of the tigers is seductive, from its exceeding simplicity. The pressure of the atmosphere being calculated at fifteen pounds to the square inch, if sugar be placed on the upper part of the tiger, and a vacuum created beneath the false bottom by pumping out the air, every square inch of the surface of the sugar is pressed in by a weight of fifteen pounds, which is sufficient to drive through the false bottom all that is liquid in the mass, and thus leave the pure crystals above, they being too large and too hard to be forced through the meshes of the wire. In practice very great difficulties occurred: if the sugar was boiled *high*, as the sugar makers term it, the syrup became so viscid as to adhere to the crystals, and the pressure of the atmosphere, instead of driving it through, had the effect of compressing the whole mass into one solid body, as hard as a loaf of refined sugar, and which could only be removed from the tiger by the aid of pickaxes and hatchets, requiring immense labor, and tearing to pieces the wire cloth, which is expensive. If the sugar was boiled *light*, as it is termed, nearly the whole battery would run through the false bottom, when the vacuum pan was discharged, and the operation, thus conducted, would clearly be not profitable. It is, therefore, evident that the mode of boiling or crystalling the sugar in the vacuum pan is the most essential point for consideration as regards the liquoring in the tigers, and that this process can only succeed by obtaining from the battery a mass, composed of firm and large crystals floating as it were in a light and fluid syrup. This object can only be attained by great art in the sugar boiler, and the mode of so doing is an application of the principles of crystallization, which you will find stated by Professor McCulloh in his report. A description of the process would carry me too far, but I may state generally, that the syrup is to be evaporated in successive portions, so that the crystals of each portion may form *nuclei*, which are successively enlarged at each fresh charge of syrup introduced into the pan; these successive charges of syrup are always small, and the fluidity of the mother liquor of the crystals is preserved by the changes of temperature and density being kept moderate; whereas

a rapid evaporation in mass of the syrup would be attended by a violent agitation, an absence of *nuclei*, around which large crystals could form, and the result would be a small and confused grain, totally unsuited for working in the tigers.

The sugar, when boiled to the proper point, flows from the pan into the tiger in a thick mass, composed of crystals floating in a fluid syrup, and being boiled at a low temperature, cools so rapidly that it frequently requires the assistance of the workmen to scrape it along the trough and accelerate its passage towards the tigers, unless the fall from the pan towards them is very precipitous. When received into the tigers it is allowed to cool for a few hours, during which time it has become thoroughly crystallised, the mother liquor of crystallization has passed through the bottom and the whole mass is then as well purged as sugars made in the open kettles are, after remaining a fortnight in the purgeries. The surface is then removed and mixed with water so as to form a thick paste, such as the refiners call a *magma* and is again spread on the top of the tiger, which is allowed to drain for three or four hours —at the end of that time it presents a color equal to the inferior grades of white Havana sugar, but the crystal is larger and more beautiful. White syrup is then poured on it, and the air pump is applied, which forces the syrup through; the syrup in its passage displaces the last pellicle of coloring matter that still adheres to the surface of the crystals and leaves the sugar perfectly white; the action of the air pump is continued for the purpose of drying the sugar in a measure, and at the end of twenty-four hours from the time when the battery was poured into the tiger, it is shovelled out in perfectly pure white crystals, and thrown on the floor of a room heated by steam pipes, where the little remaining moisture is evaporated, and the sugar is then ready for market—the entire process, including the putting it into packages, requiring a period of less than forty-eight hours.

After the tigers have been used three or four times, the meshes in the false bottom become clogged by the small crystals that are forced into them, and the steam is then let under the false bottom through the pipe before described; it melts these crystals, and with a brush, the workmen in a few minutes has the bottom so cleaned as to be ready to receive a fresh battery. This pipe is also serviceable when through a mistake of the boiler the crystalization has been improperly conducted and a crust forms in the bottom; the steam may be used to loosen it, and thus avoid injury to the wire cloth.

Notwithstanding the perfection of the results obtained by this mode of liquoring and drying sugar, gentlemen, it is not to be recommended for adoption by any one who is unable to give to it his personal superintendence, or to procure the services of an intelligent and attentive agent. It requires constant care and watchfulness, and any mistake in boiling the sugar, whether arising from ignorance or inattention, causes much trouble and labor. Sugar made from frosted or fermented canes, or from the unripe cane which is frequently cut from new ground, or from land freshly ma-

nured by a crop of peas, could scarcely be worked in them at all, and in all such cases we have found it more profitable to put the sugar into hogsheads and allow it to drain in the purgery, in the usual mode. But when the cane juice is pure and sound and from ripe cane, I have seen nothing equal to the beauty and economy of the process, when conducted with skill and care.

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NOTE K.

*On Mr. Schutzenbach's new process, by continuous liquoring.*

[Translated from a late German treatise on sugar by Schmidt, and communicated by J. P. Benjamin, esq.]

By adhering to the following rules, it is possible to obtain from raw sugar and from cane juice all the crystallizable sugar therein contained within one-half of a per cent. of the amount indicated by chemical analysis, and that in the shape of beautiful refined loaf sugar:

1st. Solutions of sugar containing any slimy or gummy matter must not be reboiled in order to obtain therefrom refined sugar, unless required by necessity; but the raw material must first be purged by other means.

2d. Slimy or gummy solutions of sugar, when reboiled, must not be boiled beyond the point which leaves from 22 to 24 per cent. of water in the solution, so that the crystallizable sugar contained in the solution may remain uninjured.

3d. Syrups must be reboiled as seldom as possible, and the crystallizable sugar contained in them must be extracted in the shape of crystals by other processes.

4th. Drainage of syrup from crystallizable sugar must be accelerated as much as possible, so as to avoid fermentation.

5th. All ingredients containing nitrogen must be avoided in defecation, and clarification must be accomplished by other means.

6th. Metal forms must be used instead of earthen ware, and the sugar must not be clayed but liquored with syrup.

7th. As far as possible all the circumstances and conditions suitable for aiding the formation of crystals in a raw material already nearly exhausted by previous working, and which, under the ordinary process, would yield no more crystals, must be united and combined.

The mode of work necessary to accomplish the ends suggested in the foregoing rules is as follows:

The crystals must first be freed from the molasses which covers them, or rather from the molasses which is mixed up with the grain into which the crystals have been crushed. Foreign sugars, as sold in Europe, contain scarcely any entire crystals. They are generally reduced to a powder, either by grinding, or from having remained too long in store, or by transportation. The first step

required, therefore, is to reproduce the crystals in order to wash them. The molasses is then separated by liquoring and drainage, and not by repeated boilings.

The crystals are reproduced by dissolving the sugar in syrup of a suitable quality, which is always on hand in every well organized sugar refinery. They must be blown up at a temperature, not exceeding 80° Reaumur, the syrup being constantly stirred so as to prevent any part of the sugar from being burnt. As soon as the solution is complete, it must be put in coolers uniting all conditions requisite to allow the crystals to form regularly, and afterwards to drain easily.

As soon as the crystallization has taken place, the sugar is placed for purging in boxes, which are so constructed as to allow the green syrup to purge freely, and the syrup used for liquoring to penetrate easily the layers of crystals. These boxes are of such dimensions as to allow of being worked with facility and regularity.

Ordinary sugar moulds are from 66 to 82 centimetres in depth; but the layers of crystals in the boxes are only 21 centimetres deep; consequently, both the green syrups and liquoring syrup run off more easily and rapidly; the draining surface being 40 to 50 times greater than in moulds, and the depth of the crystals only $\frac{1}{4}$ or $\frac{1}{7}$ as great.

If these purging boxes are not made of proper dimensions, and if the meshes of the wire cloth which form the bottom be not duly proportioned to the size of the crystals, (which must be regular,) the process, which we term *continuous liquoring*, (*clairce continue*,) cannot be used with success. By this process $\frac{1}{4}$ of the crystallizable sugar, contained in the sirop used for liquoring, are obtained, (at the same time that the liquored sugar is washed and whitened,) simply by the spontaneous evaporation of the water, which is much facilitated by the large surface which the boxes offer to the atmosphere. By this method, therefore, it is very easy to whiten the crystals of the sugar, and yet avoid the necessity of reboiling the syrup used for liquoring, as is usually done in order to obtain from it such crystals as it contains.

It is for these reasons that, by this new process, in three days, and with scarcely any expense for labor and fuel, 75 to 80 per cent. of pure white sugar are obtained from the quality of sugar called *fair brown*, (bonne quatriéme,) while, by the ordinary process, not only is there an expense in reboiling, and a loss of sugar resulting therefrom, but the result is only 55 to 60 per cent. of white sugar obtained in 10 or 12 days, if the forms are liquored, or in 25 to 30 days if they are clayed.

After thus obtaining in three days 75 to 80 per cent. of white sugar contained in the syrup, the remaining 10 to 15 per cent. must be extracted from the drainings, which require to be reworked, and which are now too heavily charged with impurities to be used for dissolving a fresh quantity of raw sugar. The sugar contained in the drainings can, however, be extracted by following, strictly, the rules above given, viz: to boil down only to a point, where there remains in the sirop 22 to 24 per cent. of water, and then to put

it, for crystallization, in vessels where it can remain for a sufficient length of time under the influence of the temperature required for forming large and hard crystals. After the crystallization is completed, the green syrup is drawn off, and the sugar is liquored with white sirops. These green syrups, which are now nothing but a mother liquor containing a large quantity of impurities, and almost wholly devoid of crystallizable sugar, are subjected to a new boiling as before, and then removed to large cisterns for crystallization.

It is indispensable to maintain a somewhat elevated temperature, in order to obtain again regular crystals from syrups boiled a second time, which, by reason of a previous crystallization, have been almost exhausted, and which are mixed with a large quantity of slimy matter. These syrups contain, on the one hand, only the thirtieth part of the crystallizable sugar contained in the raw material, and, on the other hand, all its impurities. If such syrups are boiled too high, and then exposed to a low temperature, the atoms of crystallizable sugar cannot approach each other and are lost in the mass, which has now the appearance of bird lime. If afterwards, under favorable circumstances, crystals are formed, they remain small. For this reason, stone cisterns, sheltered from atmospheric influence, should be used to promote the crystallization of such syrups, whereas in forms and other small vessels they would not yield any crystals at all. After the crystallization is completed, the mass is taken from these cisterns, the green syrup allowed to drain, and the crystals washed in the manner above described.

Brown sugars, of which the crystals are sufficiently well preserved, are put into the boxes and treated by the process of continuous liquoring, without restoring the crystals. In this case no green syrups are obtained, but the syrups used in liquoring, which have already lost too much of their crystallizable sugar and become too impure for further use as liquor, are treated in the same manner as above explained for the green syrup, which runs from sugar whose crystals have been restored.

As a general rule, only such sugars should be employed for refining purposes by the new method as have been purged and are equal in quality to the best clayed colonial sugars. After the slimy matter contained in raw sugar has been separated, it is very easily refined into such loaves as are used in commerce.

This operation is to be thus conducted: the purged sugar must be dissolved in water and the solution when of proper density is heated to the boiling point and filtered through bone black. The syrup comes through perfectly white, and is clear as water, and without being treated with finings it is boiled as usual. No alteration need be apprehended, as no slimy matter is contained in the solution. After being brought to the striking point, the sugar is raised to a sufficient temperature for granulation, by means of heaters, if the vacuum pan has been used, or by coolers if boiled under atmospheric pressure, and then filled into forms. Earthen forms should not be used, but iron forms coated with a varnish capable of bearing heat without scaling. The drawing of the green

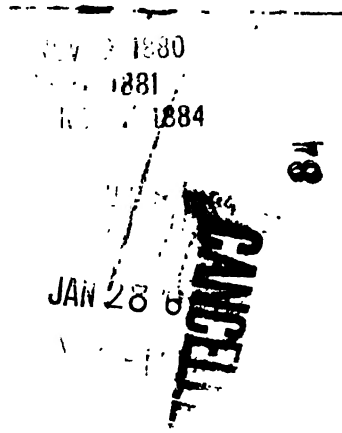
syrup, the hauling and stirring are performed as usual. In order to obtain the loaves perfectly white, they should not be clayed, but liquored with a colorless syrup, which is merely a saturated solution of pure sugar in cold water.

The prejudice against the use of syrup for liquoring is inconceivable. If clay is used, the bleaching takes place in the same manner as with syrup, because the water oozing through the clay dissolves a certain quantity of sugar. The difference is only, that in the latter case the syrup is produced in the form itself, under very unfavorable circumstances, whereas, in the former case, the syrup is previously prepared under the most favorable circumstances.

The crystallization, drainage, liquoring, and second drainage of the liquor, require seven or eight days. The loaves are taken out, the wet tips cut off and others added in their place, which is done by a very simple machine. The loaves are then reversed, allowed to remain twenty-four hours in this position, and afterwards dried in a drying room by means of a strong current of air, at a temperature which should not exceed 95° Fahrenheit, and which should also be kept up during the first twenty-four hours.

The whole process of refining, from the first dissolving of the raw sugar to the packing of the loaves in paper, requires from forty to fifty days. The product of this mode of operation, if properly conducted, is always beautiful loaf sugar of the very best quality. The size of the grain, if required large or small, depends on the skill of the boiler. The green syrup from the loaves is employed as a liquor for the sugar in the boxes, and there deposites nearly all the crystallizable sugar contained in it; this is the reason why nothing but first quality of refined sugar is obtained by the new method, without exposure to the expense and loss inherent in the old system.

Cane juice, after being converted into syrup of such density as to contain from 22 to 24 per cent. of water, so as to avoid the decomposition which would result by subjecting it to a heat sufficient to produce a greater density, should be thrown into crystalisers of a capacity of at least 200 gallons. In all other respects, as regards crystallization and liquoring, the treatment is the same as above described for raw sugars whose crystals have been restored. The green syrups are boiled down in the same manner as the syrups which give the first product. The drips are used in the same manner as those from the raw sugars, and the same principles adhered to. The first product of pure sugar is obtained in four days from the time the juice leaves the mill, the second two days afterwards, and the third on the eighth or ninth day. Consequently, in nine days we get three-fourths of the pure sugar contained in the juice. It has been previously stated that 40 or 50 days are necessary to obtain the first quality of loaf sugar. The cost of this new method is rather less than that of the old; the same product in weight is obtained, but instead of raw sugars the first quality of refined sugar produced.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